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Mayo Clinic Number

THE MEDICAL CLINICS OF NORTH AMERICA

Volume 25 July, 1941 Number 4

RADIUM IN MEDICINE: INTRODUCTION AND GENERAL CONSIDERATIONS

ROBERT E. FRICKE

Probably no other branch of medicine has aroused so much universal interest as the new science of radiology. Including both diagnosis and treatment, it has added immeasurably to achievements in the art of medicine. With its recent inception and rapid development, radiology is a growing, changing science and in the opinion of many is the most promising field in medicine today.

Much progress had been made in the art of healing by the closing years of the nineteenth century. There had been notable advances in surgical methods; the introduction of anesthesia and of asepsis and antisepsis proved to be the foundation of modern scientific surgery. Internal medicine progressed rapidly; better medical education was offered in fewer but far better medical schools.

DISCOVERY OF THE *x*-RAY AND EARLY INVESTIGATION OF URANIUM

In 1895 came something new, conceived by nonmedical scientists but quickly adopted by physicians. In that year, Wilhelm Konrad Roentgen, Professor of Physics at the University of Würzburg in Bavaria, discovered an invisible ray that could penetrate matter and affect photographic plates. Roentgen's discovery climaxed the patient research of hundreds of physicists who had been experimenting for two cen-

turies with the passage of electricity through gases and through partially evacuated glass tubes.

The popular interest in this new ray was world-wide. It is characteristic of the thoroughness of the German scientific mind that Roentgen did not report his discovery until he had experimented at length and had produced a finished and detailed study of the physical principles involved.

The discovery and immediate practical use of the new ray in medical diagnosis stimulated other physicists. The fluorescence seen in the walls of the old gas tubes during the production of the *x*-rays interested many workers. In Paris, Henri Poincaré believed that the fluorescence of the glass was necessary for the formation of *x*-rays and reasoned that fluorescent minerals also might yield invisible radiation similar to the *x*-rays. Antoine Henri Becquerel, Professor of Physics at the Polytechnical School in Paris, studied salts of uranium. This was a fortunate choice, as uranium was found later to be an ancestor of the element radium. Becquerel placed uranium minerals in metal containers over a covered photographic plate and exposed the preparation to sunlight; development of the plate revealed the appearance of dark spots where the uranium had rested. During a period of cloudy weather this preparation was left in a desk drawer for several days, but before exposing to the sunlight, with a true instinct for research, Becquerel developed the plate and found the same dark markings. He concluded that invisible rays emanated from uranium minerals and he studied the rays carefully. He found that these rays could not be refracted nor reflected and that they discharged a charged electroscope; in fact, these "Becquerel rays," as they were called, were somewhat similar to Roentgen's rays. He found that the rays were emitted spontaneously, apparently a property of the atom, from all uranium compounds and from the element uranium itself. In short, Becquerel's work, often overshadowed by subsequent research, was really outstanding and provided a secure foundation for the amazing accomplishments of the Curies.

RADIUM: DISCOVERY AND PROPERTIES

Madame Curie, of Polish birth, who was engaged at this time in research work with her husband, Pierre Curie, Professor in the School of Physics and Chemistry of the City of Paris, determined to investigate further the new Becquerel rays. She realized the value of precise measurements in this work. Hence, she decided to make these measurements by utilizing the property of the rays to discharge an electroscope. She interested her husband in the problem and they worked with residues of uranium ores obtained from the Austrian government. For this work they employed a sensitive electrometer which had been devised by Pierre Curie and his brother.

The story of the arduous labors of the Curies, who worked with poor equipment, no permanent help and miserable laboratory facilities, is well known.[3] In brief, to their surprise they found that some of the uranium ores had stronger electrical properties than pure uranium; they decided that an unknown element contained in the ore was responsible. Patient search isolated traces of the new element in each ton of pitchblende, and radium was announced as the new element in 1898. Years of labor followed; by 1910 an exact determination of the atomic weight was accomplished and the pure metal isolated.

So far the bare skeleton of the momentous discovery of radium has been traced. There was instant world-wide excitement among scientists and public alike. For two reasons the discovery opened a new era: first, it rearranged all concepts of physics and chemistry, permitting exploration of the atom and aroused hopes for future release of the tremendous atomic energy locked therein and, second, it furnished the medical profession with an entirely new method of combating civilization's greatest scourge, malignant disease.

Radium proved to be one of a series of complex unstable elements, evolving over billions of years from uranium, and itself disintegrating to form simpler elements. During this process an enormous amount of energy was being released steadily. A civilization existing on the energy furnished by

the combustion of coal became understandably interested in an element which produced a million times the energy furnished by burning coal. However, this energy was not evolved instantaneously but at a fixed gradual rate over many centuries of time, and its rate of flow could not be hurried, retarded nor harnessed for man's need of power. The long sought transmutation of elements was now a reality; the dreams of the old alchemists were at last realized and radium was studied intensively in all the laboratories of the world.

Radium disintegrates spontaneously, giving off protons (*alpha rays*) which are positively charged helium nuclei and are really particles and not true rays. *Beta rays* also are emitted; these are negatively charged particles of electricity, or electrons, similar to cathode rays in the roentgen-ray tube. *Gamma rays* are emitted too; these are true rays, similar to roentgen rays but of shorter wavelength and of far greater penetration; some of them can traverse 25 cm. of lead.

The proportion of the three types of rays or particles are as follows: alpha particles, 88.8 per cent; beta particles, 4.5 per cent and gamma rays, 6.7 per cent. The rays in this proportion are emitted from radium in equilibrium with its decay products. Radium alone yields only alpha particles; as the element is enclosed in glass or metal when in medical use. subsequent elements are formed and as they decay, yield their energy in the form of rays, all in the tiny laboratory of the tube containing the element. Hence, radium gets the credit for rays generated by its descendants. As radium emits alpha rays it decays to form *radon*, a gas which is an entirely distinct element. Radon itself emits alpha rays and becomes a metallic element known as *radium A*. Radium A emits alpha rays and becomes *radium B*. Radium B and its descendant, *radium C*, furnish the beta and gamma rays used in medicine. They are employed at a great loss of energy, as alpha rays, which carry 88 per cent of the energy, are stopped by the thinnest glass or paper and hence not utilized. To obtain these descendants of radium which yield the powerful rays needed for therapeutic purposes, a supply of radium itself is

needed, as the lower elements pass away quickly. Radium takes centuries to disintegrate: in 1690 years half of any initial supply has vanished; in another 1690 years not all the residue has gone, but just half of the remainder, and so on down through the centuries. During all this time the flow of energy is constant and dependable, an ideal characteristic for exact computation of dosage in medical work.

Radium had a fair start in life because its discoverers were, like Roentgen, true scientists. The Curies lived only for their work and refused meaningless decorations and emoluments. They refused to patent or otherwise restrict their discovery, but gave it freely to the world. Science itself is international: work proceeded in each country and ideas and records of progress were exchanged freely.

SOURCE AND SUPPLY OF RADIUM

This brings us to the interesting question of the source and supply of radium. Radium is always found in uranium ores in a fixed ratio, one part of radium to 4,000,000 of other material in the richest pitchblende. This enabled the physicists, Rutherford and Soddy, to trace the life history of uranium and deduce the formation of radium from its more complex parent. The Curies made their discovery from ores taken from the St. Joachimsthal mines in Bohemia and furnished by the Austrian government. As soon as the value of radium was recognized, the Austrian government prohibited exportation of the ore and the first monopoly was established. The succeeding history of radium in medicine is the story of monopolies of the valued metal by different governments. A world-wide search for radium began. In the United States, a low grade uranium vanadate was discovered in Colorado and Utah in the early years of this century. This was assayed in France and named *carnotite*, after the French chemist, Carnot. For years the American ore was shipped abroad, refined and purchased from abroad at high prices by physicians of the United States. Finally, about 1911, an American engineer named Patrick Flannery determined that American ore should

be refined in this country and become available to the physicians of the United States. He studied methods used abroad and organized the Standard Chemical Company, which began producing radium in 1913. The crude ore mined in Colorado and Utah was hauled to Marysville, Pennsylvania, and the laborious process of extraction performed there. Native radium became available at a cost of about $120,000 per gram. Five hundred tons of crude ore plus an equal weight of chemicals were necessary to produce a gram of pure radium. An American monopoly now existed, and for the next ten years most of the world's radium came from Colorado and Utah. Dr. Howard A. Kelly, of Baltimore, and Dr. James Douglas, a philanthropist, also formed a National Radium Institute with the United States Bureau of Mines and obtained a large supply of radium for the Howard A. Kelly Hospital in Baltimore and the Memorial Hospital in New York City.

At the outbreak of the first World War, about 1913, an extremely rich deposit of *pitchblende* (uranium oxide) was discovered in Africa in the Belgian Congo. This find was not disclosed until hostilities had ceased. This pitchblende was far superior to carnotite in its content of radium and the cost of labor was much cheaper. Hence, although the crude ore had to be transported 1600 miles to the ocean and about an equal distance to Belgium for refining, radium could now be purchased for $70,000 per gram. At that price, radium could not be produced profitably from carnotite, and gradually all companies in the United States ceased production. The Belgian radium belonged to the Belgian kingdom and proceeds helped pay the taxes of the country. Belgium supplied practically all the world's radium from 1920 to 1930.

Gilbert La Bine and his brother Charles, Canadian prospectors since childhood, discovered in 1930 a rich vein of pitchblende at Great Bear Lake, on the edge of the Arctic Circle. Activity gradually changed from equatorial Africa to the frozen North. Tremendous difficulties faced the La Bines; large sums had to be raised for initial expenses. When things looked hopeless, Marcel Pochon, a former pupil of the Curies,

brought his equipment from France and simplified the time-consuming process of extraction. About 1932, the Belgian companies dropped the price of radium to $50,000 per gram. When the Canadians were able to meet this competition, the Belgians, in 1936, again reduced the price to $25,000 per gram. Even with this reduction the rich Canadian ore could be handled profitably and the lower price proved to be a boon to physicians: three patients could now be treated when only one could be cared for before. At the outbreak of this present war, Canada had stepped up production to 108 gm. a year: the world supply was approximately 800 gm., or nearly 2 pounds, whereas the world supply in 1930 was approximately 300 gm. Laytha furnishes an interesting account of the development of the radium industry in Canada. The present war has now halted production everywhere, with more than a million dollars in unfilled orders which will have to wait.

RADIUM THERAPY

Fortunately for the new science most of the pioneers in radium therapy possessed the same high character as the Curies. The biologic effects of the element were, of course, unknown. In 1901, Becquerel carried some radium in his vest pocket; in the course of a few weeks a burn appeared on his abdomen. Pierre Curie, interested, strapped radium on the tender skin of his forearm. In due time the same effect was noted. On Besnier's advice, radium was loaned to Danlos to use at the St. Louis Hospital in Paris. Superficial epitheliomas, lupus and tuberculous ulcerations were treated empirically and in many cases healing occurred. After a three-year trial Danlos was convinced of the therapeutic value of radium within restricted limits.

Radium therapy was then placed on a *scientific* basis by the enthusiastic efforts of Wickham and Degrais, of Paris. With the co-operation of Armet de Lisle, who supplied the radium, the Biologic Laboratory of Radium was organized in 1906, with special emphasis on research and careful physical measurement of dosage. Dominici, who had not previously worked

with radium, was made director of the physiologic laboratory and of therapeutic studies as applied to medical pathology. Patients were treated with great care and careful records were kept; moreover, visiting physicians were welcomed and encouraged to study the results. Previously, only superficial lesions had been benefited by treatment. Now, with the aid of Dominici and the physics laboratories, "ultra-penetrating rays" were employed by filtering the radium through 0.1 to 2 or 3 mm. of lead. Depth dosage was improved. Wickham first added, in 1907, the principle of crossfire and cured a large erectile hemangioma on a child's forehead by the application of rays through several fields around the tumor. A perusal of Wickham and Degrais' textbook reveals the authors as most conscientious workers. The two innovations—*heavy filtration,* which enabled utilization of more penetrating rays for efficient deep effect while sparing the superficial tissues, and the principle of *crossfire,* that is, administration of heavy dosage to circumscribed deep targets—at last afforded a method of treating malignant processes deep in the body. Wickham and Degrais pointed out the specific effects of irradiation on different pathologic processes. They were also conservative and counseled that for many types of lesions, radium therapy was not a suitable method; also, that "radium acts locally, and does not play any recognized part in general infections and in distant metastases."

Meanwhile, progress was recorded in the United States. Robert Abbe, in 1905, was the first to bury tubes which contained radium into tumors. Prominent surgeons hastened to adopt the new therapy. Howard A. Kelly of Baltimore, internationally known surgeon and one of the "four doctors" who formed the teaching nucleus of the Johns Hopkins University School of Medicine, purchased his first supply of radium in 1905 or 1906.

Computation of dosage has been a complex problem in radium therapy. In the pioneer days of Wickham and Degrais, the measurement of the amount of radium salt used in treatment was very crude. Purity of the radium was gauged by

comparison of its ionization effect with that of uranium. In articles of that time "50 mg. of radium sulfate of 200,000 activity," is mentioned. This statement indicated that the radium salt was weight for weight 200.000 times more active than uranium. In 1910, the Congress of Radiology and Electricity, which met in Brussels, delegated Madame Curie to prepare an international standard for radium. In 1912 Madame Curie prepared the first standard of pure radium chloride. Since then, each country has set up a standard for pure radium salt. Any radium which is purchased in this country must be compared with the government standard in the Bureau of Standards, and by its content of gamma rays exact measurement can be made. Radium is always sold in the form of one of its salts. In this country, only the amount of the actual radium element is considered and measurement is made by comparison of the gamma ray with the standard.

Radium therapy improved in effectiveness with the active collaboration of leading *physicists*. In this country, Duane, in 1908, suggested using radon directly within malignant tumors. Janeway, at the Memorial Hospital in New York City, developed this idea and used radon in bare glass tubes. In 1914, Joly and Stevenson enclosed glass seeds containing radon in steel for temporary implantation. In 1920 Failla designed apparatus for making glass tubes for permanent implants of radon, and in 1926 developed methods for introducing the radon directly into gold tubing for permanent implantation.

Undoubtedly, work with radium was stimulated by the excellent reports of Kelly and his associate, Burnam, at the annual meetings of the American Medical Association in 1914 and 1915,[7,8] detailing results in the treatment of uterine hemorrhages and fibroids, and of carcinoma of the uterine cervix and vagina.

The concomitant advances in *clinical pathology* aided the new therapy. Changes in radium technic were guided by histologic study of irradiated tissues. In 1905, Bergonié and Tribondeau taught that immature cells and cells undergoing mitosis are especially sensitive to irradiation. Hence, tumors containing

more embryonal cells regress much more rapidly than growths formed of adult types of cells. Colwell and Russ made valuable contributions on the effect of radium on normal tissues; Ewing has worked out in detail radium effects in different types of cancer. MacCarty, Alter and Broders are other pathologists whose contributions have been invaluable, and their work has taught us much regarding the effect of irradiation and has been of decided value in prognosis.

RADIOLOGIC ASSOCIATIONS AND PUBLICATIONS

The development of irradiation in medicine can be appreciated by a glance at the organizations which have fostered and furthered the use of the new therapeutic agent. One of the earliest radiologic associations in the United States was the *American Roentgen Ray Society*. This was organized in 1900 as the Roentgen Society of the United States for the purpose of the advancement of radiology and its maintenance as a specialty in medicine. The present name was adopted in 1906. It was incorporated in 1922 in the District of Columbia and has a membership of about 461. The official monthly publication is now termed the "American Journal of Roentgenology and Radium Therapy," because it has included the published work of the American Radium Society from 1922.

The largest radiologic society in this country is the *Radiological Society of North America,* which began as the Western Roentgen Society in 1915. Its present name was assumed in 1918. The membership is about 1,242, and the monthly publication is "Radiology."

The *American Radium Society* has functioned since 1916 and now has a membership of about 125.

The *American Society for the Control of Cancer* was started in 1913 and incorporated in 1922. The membership is about 2,000. It is an educational society, and its object is to collect, collate and disseminate information regarding malignant disease.

The *American College of Radiology* has been in existence since 1923. This is an honorary organization which correlates the work of the other large societies. Prior to 1924,

radiologists met in the Section on Miscellaneous Topics at the annual meetings of the American Medical Association, but in that year a Section on Radiology was established.

Similar organizations grew up simultaneously throughout Europe. Many local societies also function in this country.

These various societies have annual meetings at which radiologists gather and present advances in their special field, later to be published in the official journals. Then too the rapidly changing technic in both radiologic diagnosis and therapy is admirably summarized each year in the "Year Book of Radiology" by Kaplan and Waters. The editors collect and abstract the outstanding contributions in radiologic literature of the preceding year.

The *American Board of Radiology* which was formed in 1924, certifies specialists in this field of work on the basis of their experience and ability and on the results of examinations given by the Board. Its work serves to protect the public and elevate the standards of radiology as a specialty.

Five International Congresses of Radiology have been held in different parts of the world. Since radiology plays such an important role in the treatment of cancer, radiologists have great interest also in the International Cancer Congress held every few years.

COMMENT

In the struggle of medical science to overcome malignant disease, radium therapy plays an important but not exclusive role. Surgical procedures, electrosurgery, radium and roentgen therapy are necessary to conquer the complex of diseases grouped under the term "cancer." Every practicing physician should know that these four methods are the only scientifically proved means of treating cancer. In a recent survey, the American Society for the Control of Cancer found that in 30,000 proved cases of malignant disease five-year cures had been achieved by surgical procedures and irradiation. Since cancer starts as a local disease, the earlier irradiation therapy is instituted, the more effectively the disease can be treated. If metastasis and extension have occurred, palliation is all that can be offered.

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As a final word, Wickham's conclusions in the preface of the Wickham and Degrais textbook published in 1909 and 1910 are still valid:

"Radiumtherapy is indeed a very complex and delicate weapon to handle. Long and thorough personal experience is necessary, in order to turn it to the best account, to learn to distinguish accurately the cases for which it is most suitable, and to avoid injuring patients, either by badly proportioned doses or by depriving them of other therapeutic measures, which might prove more successful."

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THE DIRECTION OF THE THERAPEUTIC EFFORT IN CASES OF CARCINOMA OF THE UTERINE CERVIX

HARRY H. BOWING

Study and research have advanced our knowledge of physics and chemistry for the therapeutic radiologist, and in turn, he supplies his judgment, skill, care and energy in the art of medicine and surgery to obtain the ultimate purpose for which his endeavors have been put forth, that is, the restoration of his patient who has malignant disease to health or, at least, to a renewed hope.

GENERAL CONSIDERATION

Today, surgery, radium therapy and roentgen therapy are recognized as well-established procedures to employ in the treatment of patients who have malignant disease. Their range of application to meet the individual requirements of the case under consideration seems to be unlimited. They can be employed singly or in many combinations, and further, they can be employed as conservative or as radical methods. Their intensity, timing and spacing are appreciated in a measure, but are far from being well understood.

A medical, surgical and laboratory staff with knowledge, judgment, skill and physical equipment is essential for the treatment whether designed for "cure" or palliation in any given case of malignant disease.

Briefly stated, for the present, *sound treatment of cancer is a combined, co-ordinated and co-operative affair*, since it is impossible for any one person to master the various procedures, as well as own and manage the necessary physical equipment. Specialization and centers for treatment are essential

for good results and productive of research. At best, the aforementioned methods of treatment are a local, regional or partly general attack on the disease. There is no generally accepted method for the systemic treatment of malignant disease.

Definite rules cannot be formulated; however, the important factors are (1) the *diagnosis* with the estimation of the extent of the primary and secondary malignant lesions, (2) the *type of treatment* to be employed and (3) the *results* to be obtained.

Our knowledge of malignant disease has advanced definitely, both in extent and depth, and yet the causation of the disease is, in the main, unknown. Many data have accumulated to indicate that the disease has a focal point of origin, and with this consideration, the beginning or onset phase of the disease is, apparently, without signs or symptoms. However, in lesions on the surface of the body or in body cavities suitable for endoscopic examination, the initial phase may be detected at an early stage. The focal point of origin may begin as such, or it may have its origin in an apparently simple or nonmalignant lesion, as a secondary or degenerative change. The latter is designated as a *premalignant* lesion.

Little is known about the *systemic changes* which precede or follow the beginning of the focal point of origin. Theoretically there must be some general phenomenon occurring within the patient who has malignant disease to establish, accelerate or retard the new growth. There is no accepted laboratory test for the determination of the presence or absence of the substance or substances associated with the possible systemic change or changes. One can support the patient in every possible way in order that she will well tolerate and recover from the procedure or procedures best suited for her individual care.

THE DIAGNOSIS

History.—To avoid an involved presentation of this topic we can conclude that the causation of carcinoma of the uterine

cervix is unknown, and that in the average case diagnosis furnishes very little difficulty to the clinician. One must not be misled by the duration of the signs; instead, one should accept the facts, rather than be influenced unduly by them.

SHOW OF BLOOD.—The show of blood in some form is the most common single sign. During the menstrual life of an individual, a slight irregularity from the genital tract usually does not startle the patient. It may recur from time to time, especially with trauma, for example, following sexual intercourse or taking a douche. Fear may enter in, however; the patients put off visiting their physicians, assuming that, since the show is slight, it should be quite trivial. As the months go by, the bleeding becomes greater and may be related, in part, to the menstrual flow, and again the assumption is that it cannot be serious. Finally, it becomes continuous and now other associated phenomena are present, probably odor and pain. Valuable time has been lost; the appearance of extra-menstrual bleeding or bleeding from the genital tract regardless of the occasion, the age of the patient, and so forth, should be considered an important clue, and everything possible should be done to place the proper interpretation upon so important a sign. As the disease advances, the bleeding may become very severe and very difficult to control. Secondary anemia, usually from a direct loss of blood, is the most common complication observed in the group now presenting themselves for our consideration.

ABNORMAL VAGINAL DISCHARGE.—The next sign of consequence would be a *watery* or *mucous* discharge varying in character and amount. The functioning of the genital structures does furnish, normally, a certain amount of secretion, especially before and after menstruation, and it seems difficult for the average patient to differentiate the normal from an abnormal discharge. It seems reasonable to assume that the early lesions would not irritate the structures and thus provoke a discharge. As the growth advances, especially if it is an adenocarcinoma, the functioning of the malignant parenchymatous elements may furnish an excessive amount of mucous

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THE DIAGNOSIS

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Pain from Obstruction to the Flow of Tissue Fluids.—The malignant and inflammatory infiltrations in the parametrium and pelvic lymphatics with resulting fixation of pelvic structures and eventual obstruction to the flow of blood and lymph, result in varying degrees of edema of the vaginal walls, especially the anterior, edema of one or both lower extremities, edema of the external genitalia, and so forth. The edema in the anterior vaginal wall may bring about various urinary complaints, especially a "slowing up" of the emptying time of the urinary bladder. The enlargement of the lower part of the leg or legs does interfere with movements and does cripple the patient. Edema of the external genitalia, as a rule, does not occur singly and usually is a late manifestation. *Difficult urination* and *"burning"* are complaints.

Pain from Obstruction to the Flow of Urine.—As the primary lesion advances and the secondary deposits occur and enlarge, the function of the urinary bladder and rectum will be disturbed. The obstruction to the flow of urine may bring about three separate complications, each with a train of symptoms and signs. Probably the most common site of obstruction is in the region of the base of the bladder. There may be an actual anatomic obstruction, or the walls of the structures may be involved, causing physiologic obstruction. The ureters may be involved, bringing about various degrees of *hydronephrosis* or *pyonephrosis*. The trigon may be infiltrated as well as the mucous membrane of the bladder wall, resulting in *urinary retention* and *cystitis*. Infiltration of the anterior vaginal wall may bring about *distention of the bladder* and cystitis on account of urinary retention. As a rule, the diagnostic signs and symptoms of injury to the urinary system are minimal; therefore, any patient with apparently trivial urinary complaints should be subjected to a comprehensive investigation of the genito-urinary system, especially if the plan is to apply adequate treatment for clinical recovery.

Urgency, frequency, dysuria and *nocturia* are common. The results of simple urinalysis may be negative, and if the symptoms warrant a further urinary study, a catheterized

discharge. The colloid carcinoma, a rare type of cervical lesion, does furnish, after it has reached a fair size, an inordinate amount of thick, clear mucus. As soon as secondary infection becomes a complicating factor, depending upon the amount and virulence of the infection, a vaginal discharge may be a resulting phenomenon. Naturally, as the lesion advances, necrosis enters in, and then there are many factors, both normal and abnormal, to bring about and maintain a serosanguineous odorous vaginal discharge typical of the average stage 3 lesion encountered today. The *foul, fetid odor* of advanced carcinoma is so typical that there is little room for its misinterpretation.

PAIN.—The pain associated with cervical carcinoma is typical and may be grouped under two headings: (1) obstructive type, and (2) nerve or neurogenic type. The obstructive type is, no doubt, the earliest variety encountered, and may be subdivided as follows: (*a*) obstruction to the flow of secretions or discharges; (*b*) obstruction to the flow of blood and lymph; (*c*) obstruction to the flow of urine, and (*d*) obstruction to the flow of intestinal contents.

Pain from Obstruction to the Flow of Secretions or Discharges.—The infiltrating lesions of the supravaginal portion may cause a functional or an anatomic block to the flow of the glandular secretions from the uterus. An accumulation of this secretion in the uterine cavity, with or without secondary infection, brings about or stimulates uterine contraction, and when the latter is sufficiently severe, the patient complains of a characteristic "labor" or "menstrual" pain or discomfort. Some describe it as a "pressure pain" or "bearing-down pain" low in the abdomen. Some patients may admit the sudden passage of a varying amount of vaginal discharge usually with odor, and then they will be relieved of the distress until a time has elapsed sufficient for the uterine cavity to fill again. This type of complaint may be interpreted as the result of coexisting hydrometritis or pyometritis. The obstructive type of pain is classic for the carcinomatous involvement of the supravaginal portion.

on the nerve trunks, causing actual pressure atrophy, (2) the factor of obstruction to the flow of blood and lymph to the nerve elements and (3) actual infiltration or involvement of the nerve structures with malignant cells, that is, within the nerve sheath. The typical pain is described as a "dull ache" occurring low in the back, usually unilateral and referred down the leg on the same side. Usually it is worse at night and may disturb the patient's sleep. A neurologic examination may elicit the actual distribution or involvement of the nerves.

Palpation.—A good history is most valuable in that the examining physician can visualize the probable extent of pelvic involvement and then proceed with the palpation to elicit the amount of structural involvement. A routine procedure is of definite value. For example, one should begin by palpating the inguinal regions for *enlargement of the inguinal nodes.* When involved, they may indicate a probable primary carcinoma of the uterine fundus with late involvement of the cervix, or pelvic involvement from an extrapelvic malignant lesion, or a primary carcinoma of the external genitalia or genito-urinary system. *Secondary deposits* low in the vaginal tract may metastasize to the inguinal lymph nodes. Careful palpation of the external genitalia, and especially of the hymenal region, is necessary to rule out secondary deposits, since this ring may be infiltrated. As the examining finger is inserted slowly in the vagina, one should palpate all vaginal walls for secondary malignant deposits, and finally, carefully palpate the extent of *cervical infiltration* and *regional infiltration* of the vaginal wall. Great care should be exercised when palpating the cervical infiltration in the presence of vaginal bleeding and especially so with a history of hemorrhage and a resulting secondary anemia.

A *bimanual vagino-abdominal and recto-abdominal examination* should be done in a very gentle manner; otherwise, one's efforts will be met by resistance upon the part of the patient, and unnecessary trauma may occur. The finger in the vagina is held gently against the cervical infiltration. The hand upon the abdomen should press very gently with the fingers wide open, fan-like, on the abdomen. Palpation should

specimen should be obtained. A simple *cystoscopic examination* may be very informative. It may disclose deformity of the wall of the bladder from extravesical pressure, or edema of the vesical mucosa. There may be actual ulceration or secondary involvement of the vesical mucosa. *Biopsy* of the vesical lesion should be made when these findings are present. This finding may indicate the presence of a potential or actual vesicovaginal fistula. Further observation may elicit the presence of an irregular or scanty discharge of urine from one of the ureteral meatuses, indicating rather clearly an obstruction to the urinary flow in the presence of unilateral hydronephrosis. An *intravenous urogram* should be the next consideration. A *blood urea determination* is the most valuable single laboratory test for patients who have given a history of urinary distress, and yet in the presence of extensive renal damage, the blood urea may not be abnormally high. The obstruction to the flow of urine from the ureters and the urethra may be functional or anatomic.

Pain from Interference with Movement of Intestinal Contents.—The rectal distress resulting from interference with the movement of the intestinal contents usually is described as "constipation" or difficulty in obtaining a satisfactory bowel movement. Some patients may complain of rectal pain at the time of evacuation. Some may need cathartics and enemas for relief. Seldom is there actual involvement of the intestinal mucosa. When this is present, a potential or actual rectovaginal fistula is a complicating factor. The pelvic infiltration may press upon the bowel, limiting its lumen, or it may distort or further limit the normal slight movement or play of the bowel. In some cases, the lumen of the bowel is reduced greatly by a perirectal infiltration, causing a rather severe obstruction, and yet colostomy seldom is done for relief, since a low residue diet and mild saline cathartics and oil enemas may suffice. A proctoscopic examination should be considered in all cases in which there are rectal complaints.

Neurogenic Pain.—The neurogenic type of pain may be due to several factors, for example (1) the factor of pressure

features. The ordinary examining or operating table top is quite sufficient. The knees and the chest should be on the same plane. The thighs must be perpendicular to the table top. The patient is draped with two small sheets or one large sheet with a suitable slit in the mid area. The position can be assumed without exposure that will embarrass the patient. As the patient becomes accustomed to the procedure, she can maintain the position with little or no effort on her part. With a Sims' speculum and some type of direct light, ample exposure of the cervix and the regional vaginal walls is obtained. The physician is in a comfortable position for the task of careful inspection of the vagina.

The examining physician gently retracts part of the vulva with his left hand. This separation of the external genitalia permits air to enter the vagina, and, at the same time, distends the vaginal walls to their capacity. The lubricated speculum is inserted easily. The perineal body is lifted upward gently. The trauma associated with the other positions just mentioned is avoided definitely. The secretions and blood clots can be removed carefully and the genuine character of the primary and secondary lesions determined at will. The cervical canal in the moderately advanced or advanced cases usually can be identified with a uterine sound. A satisfactory area of the malignant involvement can be selected for the removal of suitable or representative material for microscopic study.

The recognition of the *small* or *early* lesion is a problem. The very early lesion may be without signs or symptoms; however, a routine physical examination or the so-called yearly examination, including a satisfactory exposure of the vaginal cavity, may find the lesion before the patient is aware of its presence. In order to diagnose early tuberculosis of the lung a routine roentgenogram of the chest is made. Workers in the field of diagnosis have proved definitely that this method will detect the early phases of tuberculosis before signs or symptoms develop. A similar principle applies to the detection of carcinoma of the uterine cervix. Therefore, let the examining physician carefully inspect the vaginal cavity of every female

begin high up above the umbilicus, and gradually proceed downward to the lower abdominal quadrants. The size, position and contour of the uterus should be determined, or at least, an impression of the findings should be recorded. A bimanual recto-abdominal palpation should supplement the vagino-abdominal examination, for this is the best procedure to confirm one's previous findings and to elicit the region of cervical infiltration, the size and position of the uterus, the extent of infiltration of the broad ligament and fixation of the pelvic structures. An extra-uterine mass may indicate a primary ovarian carcinoma secondarily involving the uterus. For advanced carcinoma of the cervix, one should palpate the pilot node area in the right or left cervical region for infiltration of lymph nodes.

Inspection.—There are several approved methods of visualizing a cervical lesion: (1) the dorsal position, (2) the Sims' position and (3) the knee-chest position. The *dorsal position* is the customary one employed by the examining physician, since inspection usually follows the bimanual vaginal and rectal examination. It is less demanding upon the patient in that she does not have to rearrange herself or assist much in the maintenance of this position. However, the examining physician may be placed in an awkward position, in order to see the involvement of the cervical and vaginal wall adequately. Bleeding may obscure the field and at times difficulty is experienced in removing the blood clots in order to inspect the cervical lesion adequately. Also, trauma may be produced by the bill of the speculum.

The *Sims' position* has a very limited place; however, it is of value in examining very weak patients, for example, patients who have spent much time in bed. Markedly obese patients or crippled patients may be able to assume and maintain only this position.

The *knee-chest position* is the most satisfying position yet devised, for all concerned, regardless of the purpose intended. A few words of instruction to the patient will assist greatly in obtaining her co-operation. There are certain important

Primary Carcinoma of the Uterine Corpus with Secondary Involvement of Cervix.—Given a patient in the middle or late fifties who has a history of vaginal bleeding, bimanual palpation reveals the uterus to be anterior in position, movable and slightly enlarged for patients of that age. Inspection in the knee-chest position shows the margins of the external os to be irregular and slightly protruding. There is a definite loss of tissue in the canal of the lower uterine segment. The uterine cavity can be sounded. The uterine canal is irregular and nodular. No matter how gently the uterine sound is passed there will be bleeding from the uterine cavity. With the sound in the uterine cavity, the amount of uterine infiltration or weight of the uterus can be judged to be greatly increased, by attempting to lift the uterus with the uterine sound together with the characteristic firm, hard, irregular uterine wall. The primary lesion is a primary carcinoma of the uterine corpus with secondary involvement of the cervix.

Primary Ovarian Carcinoma Secondarily Involving the Uterine Cervix.—There are two main considerations here. The first is the finding of an enlarged ovary regardless of size, and the second is a biopsy. The histologic type of cell may indicate that the lesion is probably not a primary cervical carcinoma. The gross appearance alone of this secondary lesion will not establish the true diagnosis.

Primary Carcinoma of the Vaginal Wall with Secondary Involvement of the Uterine Cervix.—The most reliable single procedure to establish the differential diagnosis is the knee-chest position, previously mentioned. One should try to locate the cervix: since it is a fibromuscular structure, it will resist, to a great extent, invasion by the adjacent malignant process. In some cases one may locate the cervical canal with its characteristic normal anatomic resistance when a uterine sound is introduced. For a normal uterus, the sounding of the region of the internal os will elicit pain, menstrual in character, indicating rather clearly that the uterine structure is probably not the site of the primary lesion.

So far, only malignant lesions have been mentioned in the

patient, and especially so if she has borne children or had any mechanical manipulation done on the cervix and is in or around the menopausal age.

Biopsy.—The biopsy is done for two reasons: (1) to confirm the clinical diagnosis, and (2) to estimate the grade of malignant change. With the patient in the knee-chest position, speculum and proper lighting, a site can be selected. The field from which a specimen is taken for biopsy should be free of necrosis and exudation. The eversed or denuded surface usually furnishes material; when studied microscopically, a specimen from this site usually gives a high percentage of positive reports. A bit of tissue removed with a tracheal biopsy instrument is quite sufficient. There is very little, if any, risk attached to this procedure.

To sum up, the history is very important. Careful palpation and bimanual vaginal and rectal examination are essential. The knee-chest position gives the most adequate exposure. The biopsy is done to confirm the clinical diagnosis and for estimating the grade of malignant change.

THE DIFFERENTIAL DIAGNOSIS

Owing to the extent of the malignant disease, in some cases the primary site of the disease may be disguised. There are three main primary malignant diseases that may cloud the picture or diagnosis and must be kept in mind from the standpoint of differential diagnosis. The most common is probably primary carcinoma of the uterine body with eventual involvement of the lower uterine segment. The second would be primary carcinoma of the ovary with secondary involvement of the uterus. The third lesion for our consideration is primary carcinoma of the vaginal wall in the adjacent cervical regions.

Space will not permit a complete evaluation of this topic. However, briefly stated, it may have some importance. Inspection of the vaginal cavity with the patient in the knee-chest position is the most simple procedure to furnish the important leads to separate these primary and secondary lesions.

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differential diagnosis. The average condition for diagnosis today is the classic stage 3 lesion, and there is no inflammatory or nonmalignant lesion of this extent that could be confused with or mistaken for an epithelioma of the uterine cervix. The importance of the differential diagnosis is to classify the case properly in order that the proper treatment may be outlined and applied. A mistaken diagnosis may lead to the treatment of a secondary lesion and to failure to discover the primary lesion.

ANATOMY

An exact knowledge of the anatomy of the female generative organs is essential from the standpoint of diagnosis and radiologic treatment of carcinoma of the uterine cervix.

The normal *uterus* is about 7.5 cm. long, 5 cm. broad and 2.5 cm. thick. The divisions are the fundus, body and neck. The *fundus* is above a line joining the two openings of the fallopian tubes at the cornua. The *neck* or *cervix* includes 2.5 cm. of the lower portion of the uterus. It is subdivided into the *portio vaginalis,* that part protruding into the vagina and the *portio supravaginalis,* that part immediately above the vagina. Between the neck and the fundus is the *body.* The cavity of the uterus is small. The opening through the cervix is the *cervical canal;* it opens into the vagina by the external os and into the uterus by the internal os. The cervical canal is narrowed at both the external os and the internal os so that a sound passes with difficulty into the uterine cavity. The uterus is most firmly fixed to the vagina and its upper portion is most movable. It lies between the bladder anteriorly and intestines and rectum posteriorly. It is in contact with the bladder, no intestines intervening. Normally it inclines anteriorly. There are additional attachments of the uterus to the surrounding parts. The *uterovesical fold* is an anterior reflection of the peritoneum from the uterus at the level of the internal os to the bladder. Posteriorly the peritoneum descends from the uterus over the posterior surface of the upper portion of the vagina for 1 or 2 cm. and thence onto the rectum, forming the rectovaginal fold. Three *ligaments* are on each side

of the uterus. The broad ligament is the largest and most important, forming a diaphragm which extends from one side of the pelvis directly across to the other side of the pelvis. The pelvic attachments are very wide. Between the layers the fallopian tubes, the ovarian and uterine vessels, and the lymphatics, the ureters and the round ligaments are found.

The *ovary* is about 4 cm. long. 2 cm. wide and 1 cm. thick and is connected with the posterior surface of the broad ligament. It lies longitudinally or obliquely against the outer wall of the pelvis with the ureter just behind and below its posterior edge.

The *vagina* is about 7.5 cm. long. At the vulvar onset the lumen is small and in the mid and deep portions the lumen is large. Its capacity for dilatation is limited by the bony pelvic walls. Anteriorly its upper portion is in relation with the bladder and its lower portion is in relation with the urethra. Posteriorly, its upper 1 or 2 cm. is in front of the peritoneum and below lies the rectum. Laterally, the ureters are close to the vagina and about half way up they empty into the bladder.

The pelvic portion of the *ureter* is about 10 cm. long and follows the wall of the pelvis downward just posterior to the ovary. Near the floor of the pelvis, it bends forward to pass through the base of the broad ligament (parametrium). It is about 1.5 to 2 cm. outside the cervix, and inclines inward and forward along the sides of the anterior vaginal wall to enter the bladder.

The *uterine artery*, a branch of the internal iliac artery, passes almost horizontally inward toward the lower portion of the cervix. Approaching the cervix, it gives off a cervicovaginal branch which passes to the upper part of the vagina, inclines upward, reaching the side of the uterus at its junction with the vagina, and continues upward to the cornu above.

The cervix has three sets of *lymphatics:* (1) A set passes outward and upward along the side of the pelvis anterior to the ureter to empty into the nodes along the iliac artery. (2) A set passes backward behind the ureter to empty into a node

on the anterior division of the internal iliac artery. (3) A set passes from the posterior surface of the cervix almost directly backward in the uterosacral ligament to empty (*a*) into the lateral sacral nodes high up in the hollow of the sacrum and (*b*) to empty into the nodes of the promontory.[2]

HISTOLOGY

Stratified squamous epithelium covers the vaginal face of the cervix. Occasionally about 1 cm. from the external os the opening of a gland may be found. The investing layer differs from skin in that there are no hornified layer, no hair follicles, no sebaceous glands or sweat glands and no zone of pigmented cells.

The cervical canal is lined with a single layer of thin, high, columnar epithelial cells. There is an abrupt termination at the level of the external os and internal os. However, the layer may extend beyond those borders. There is no cervical stroma. There are numerous large complex racemose glands which dip into these fibromuscular bundles; they are lined with high. columnar epithelial cells.[7]

GROSS PATHOLOGY

Our experience concerns chiefly the stage 3 and 4 carcinoma of the uterine cervix. In 1839 Herbert Mayo described these extensive lesions as follows:

"The os uteri is liable to scirrhus; or the texture of the cervix or entire womb may become of cartilaginous hardness; after which ulceration commences at the cervix, leading to . . . . destruction . . . . The ulceration spreading. destroys the cervix uteri. and extends into both the bladder and rectum." And further: "Medullary sarcoma of the uterus is more frequent than scirrhus: it generally commences at the cervix uteri, a soft fungus growing from which is often for a time the whole extent of the disease. Afterwards the vagina and bladder become involved."[3]

His personal knowledge of carcinoma of the uterine cervix

recorded then coincides with our observations of today; however, my impression leads me to conclude that the infiltrating (scirrhous) type of lesion predominates. Briefly stated, there are two accepted types: (1) the *medullary* (eversing) type and (2) the *infiltrating* (inversing) type. Microscopically high grade epitheliomatous lesions predominate. The minority are made up of low grade lesions, usually adenocarcinoma.

TREATMENT

Dr. W. J. Mayo stated that *pathology* is the foundation of scientific medicine. Without a correct understanding of the nature of disease the practice of medicine as a science would not be possible. Postmortem pathology represents terminal conditions and is very valuable for teaching purposes; while living pathology deals with disease in the living, when the condition is still curable, or a restoration to the normal or physiologic condition can be brought about by appropriate therapeutic measures, and to this end the art of medicine is directed. Further, "Surgical investigation, like Hunter's pathology, was based upon the macroscopic evidence of disease. The surgeon exposed the parts to sight and, after making his examination, proceeded as appearances seemed to indicate."[4]

The Role of Irradiation.—These fundamental principles should guide the therapeutic radiologist and especially the radium therapist in the treatment of carcinoma of the lower uterine segment. Radium therapy has its widest range of application when employed as a surgical procedure. The most effective method of treating malignant disease of the uterus is through the surgical approach.

Today, the direction of the therapeutic efforts in cases of carcinoma of the uterine cervix chiefly concerns the therapeutic radiologist. Surgical management has a minor role to play and yet a very important one. The average patient who has carcinoma of the uterine cervix, presenting herself for consideration, is in the typical stage 3 involvement. More than 90 per cent of all patients coming to the Section on Radium

Therapy at the clinic are in the advanced or unfavorable group, and therefore, beyond hope for any type of radical surgical intervention. However, with care and judgment in their treatment with radium therapy and roentgen therapy, all patients can be benefited, and a surprising number of them will survive for five years and beyond. The morbidity and mortality rates associated with the treatment are extremely small. The convalescence of the patients is rather prompt and the hospitalization is minimal, a worth-while achievement, when one considers the potential illness attending the average patient. From an economic standpoint, alone, irradiation therapy has much to offer to the patient and all concerned.

Technic and Results of Irradiation.—The technic and results have been described,[1] however briefly stated. The radium treatment is an intense, broken-dose method, judiciously controlled to meet the individual needs of the patient. The time required is about three weeks for the radium therapy and one week for the following supplemental roentgen therapy. The systemic effects from the radium therapy are minimal and seldom require any special treatment. The intra-uterine application of radium does bring on some general reaction such as anorexia, nausea and, in some cases, vomiting; as a rule, the reaction is transitory and responds to simple measures. The morbidity and mortality rates are very low. The latter is 1.0 per cent. A careful follow-up should be made for the first year or two and every year after the third year.

Extent of the Lesion.—All patients are examined and treated in the knee-chest position as previously described. The first consideration should be the extent of the primary and secondary lesions. A classification of cases based on anatomic location and extent is fundamental. The stage of the lesion is a very suitable term with numbers indicating the degree of involvement. For example, a *stage 1* lesion is small, limited or characterized by early involvement. A *stage 2* lesion has extended moderately beyond the primary site. A *stage 3* lesion has a wide local extension with fixation, and a *stage 4* lesion is characterized by extreme local involvement with wide fixation

and probable or apparent metastasis elsewhere. In terms of an older interpretation, the words, early, borderline, late, hopeless, would correspond to the numerals 1 to 4.

Temporal Relation of the Radiologic Therapy to Surgery.—The treatment could be classified according to its temporal relation to the surgical intervention, for example, (1) preoperative, (2) postoperative, (3) at operation and (4) nonoperative. The intensity of the procedure could be stated as conservative or radical, and further, the radium therapy at least, could be subdivided into (1) complete, (2) limited, (3) prophylactic, and (4) abandoned. A complete treatment is characterized by apparently sufficient local treatment, and at the same time, is well distributed in the involved structure. A limited treatment is designed for palliation only. A prophylactic treatment is, as a rule, a postoperative procedure, following radical surgical intervention. The abandoned treatment indicates that any of the former types was discontinued or stopped for any reason whatsoever.

Results.—Some patients respond promptly to treatment and the condition remains arrested for many years. Other patients will respond in a similar manner, but the effect of treatment will not stop, and as time passes, radionecrosis or a slowly healing ulcer will occur. Some patients have a slow or tedious postirradiation convalescence on partial or inadequate treatment and yet will survive for five years and beyond. Some patients will obtain a perfect local result but after ten years and beyond, painful conditions due to regional metastatic gland masses will develop. In a relatively small number of cases "dual" carcinomas or unrelated malignant lesions will develop. These few examples will indicate that there is a definite systemic phenomenon in the behavior of the patients to the disease, as well as the treatment supplied. The majority of the favorable responses to well-planned treatment are satisfactory; however, one must anticipate irregularities occurring.

Theoretically, then, if these lesions are dealt with thoroughly and adequately in the early or beginning stage, the chance for cure is great, and naturally, if the lesions are treated

in the late or advanced phases of the disease, palliation is about all that can be expected.

SUMMARY AND CONCLUSIONS

Today, surgical treatment, radium therapy and roentgen therapy are the best procedures to employ in the treatment of carcinoma of the uterine cervix, either singly or in combination. This is equally true for adequate treatment of the primary and secondary lesions, as well as the treatment of the initial and late associated complications as they arise.

Most carcinomas of the uterine cervix seen today for treatment are in the advanced or inoperable group; therefore, irradiation is the best procedure for the primary and secondary lesions, and further irradiation or surgical treatment for the initial and late associated complications.

The diagnosis is another simple procedure which includes the history, palpation, bimanual recto-abdominal palpation, inspection and biopsy. The differential diagnosis is more tedious, since not every carcinoma occurring in the region of the lower uterine segment and vaginal vaults is a primary carcinoma of the uterine cervix.

Surgical procedures and the allied radium therapeutic procedures for carcinoma of the uterine cervix, regardless of stage of involvement, are the most effective when they can be employed adequately and judiciously and, therefore, should be the first treatment considered followed by supplemental roentgen therapy.

The medical profession, or better still a professional staff, should co-operate and co-ordinate completely, in order to obtain the utmost from their experience and physical equipment for the best interests of the patient. Their judgment and skill based upon their knowledge and experience will be reflected in the immediate results and the late or five-year and beyond rate of cure.

The education of both the medical profession and the laity in the recognition of signs and symptoms of malignant disease and better still of fundamental pathology will advance our

knowledge of carcinoma of the uterine cervix, and it is hoped that for the future, more applicants for treatment will be seen earlier in the disease, and if possible, at the very onset of the malignant change.

The following conclusions may be drawn:

1. One should not fail to make the proper diagnosis of carcinoma of the uterine cervix. Failure in this regard may cost the life of the patient.

2. One should select the proper therapeutic procedures to meet the individual requirements of the patient. Surgical treatment, radium therapy and roentgen therapy in combination should be recommended.

3. A careful follow-up system is necessary, since some of the early secondary lesions are symptomless in onset. Cautious treatment will prolong the period of palliation.

4. The outlook for the patient who has carcinoma of the uterine cervix is increasingly hopeful, and especially so, if education of the medical profession and lay people will awaken their eagerness to have the condition diagnosed when the lesion is confined to the lower uterine segment. Patients who have stage 1 and 2 lesions have the best chance for survival.

5. We are primarily physicians and, therefore, must accept the responsibility of doing the utmost at all times for the safety, care and restoration to health of a patient who has carcinoma of the uterine cervix, regardless of the extent of the involvement. Evidently, the patient whose condition is apparently hopeless has, nevertheless, a chance for recovery.

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RADIUM THERAPY FOR CARCINOMA OF THE FEMALE GENITALIA

ROBERT E. FRICKE

In this presentation, discussion of treatment of carcinoma of the uterine cervix will be omitted. Carcinoma of the cervix is a major problem, best handled by radium therapy, and is discussed elsewhere in this symposium.

Carcinomas of the ovary, tube, body of the uterus, vagina and vulva present difficult therapeutic problems. In the fortunate instances in which diagnosis can be established early and in which the general condition of the patient is favorable, radical surgical operation followed by irradiation is the treatment of choice.

CARCINOMA OF THE OVARIES AND FALLOPIAN TUBES

Malignancy in these situations constitutes a "silent" type of disease. That is to say, unless routine pelvic examination discloses a mass in the region of the adnexae, usually there is no indication of serious trouble until widespread extension of the disease has occurred.

There are many forms of solid and cystic tumors of the ovary, both unilateral and bilateral. The majority of these tumors are benign, although malignant degeneration may eventuate. Malignant ovarian tumors usually are bilateral. All the malignant tumors tend to grow, and often perforate surrounding structures and metastasize. Common sites of *metastasis* are the uterine fundus, cervix and vaginal walls. Direct extension may involve the urinary bladder or the rectum. Prognosis varies tremendously when a primary malignant lesion or a metastatic lesion is encountered. Consider the dif-

ference in "curability" between a primary carcinoma of the breast, for instance, and a tumor of the brain which has metastasized from the carcinoma in the breast. The tendency of the ovarian carcinoma to metastasize always must be remembered. In such a circumstance a skilled pathologist can furnish the greatest aid to the radiologist. In many instances a specimen for biopsy can be taken from an apparent primary carcinoma of the cervix or vaginal wall. The well-trained pathologist can grade the tumor and report it as a tumor which probably metastasized from an ovarian tumor. Such a procedure in such a circumstance undoubtedly would alter the plan of treatment and change the prognosis.

Surgeons have found that whenever excision of ovarian carcinoma is possible, radical extirpation of the pelvic organs is demanded. In the early years of gynecologic surgery, simple ablation of the ovaries for small malignant growths was often followed by the appearance of cancer in the body of the uterus. Conservative removal of the body of the uterus might be followed by malignant growth in the cervical stump or in the vaginal walls.

Today, the preferred treatment of ovarian or tubal malignant processes is *radical surgical extirpation* of the pelvic organs when possible, followed by *precautionary irradiation.* Ten days or two weeks after the operation, when all skin sutures have been removed and healing is well started, radium treatment is administered. This consists of two or three vaginal applications of radium, one a day, the number of treatments depending on the size of the vaginal cavity. In each application the radium occupies a different situation; in one application it is placed transversely across the vaginal vault; in one it is placed along the right vaginal wall and in one it is placed along the left vaginal wall. The applicator used is fairly bulky and carries its own protection. Following the radium treatment, roentgen ray therapy is instituted Four to six fields around the pelvis are selected, depending on the size of the patient, and one field per day is irradiated.

After surgical dismissal, the patient is instructed to return

in three months for careful examination. At the first revisit the course of roentgen ray therapy usually is repeated, but further radium treatment is not given unless definite evidence of carcinoma is found.

Since most ovarian carcinomas are of a high grade and since recurrence is fairly common, careful follow-up of each patient is essential. Re-examination of the pelvis at definite intervals is the only way in which recurrence in the incipient stage can be detected.

Thus, although radical surgical treatment and postoperative irradiation offer considerable hope of cure in early lesions, the cases in which such procedures have obtained favorable results are all too few. In the majority of cases, diagnosis is made late, when the condition is inoperable. Cure is rare, but valuable palliation is possible of attainment through employment of intelligent methods of irradiation.

In fine, treatment consists of intravaginal applications of radium and the use of roentgen ray therapy. With the patient in the knee-chest position, the vaginal cavity is ballooned out with air so that the vaginal walls can be carefully studied. In many cases radium can be placed within the uterine fundus and cervix as well as in the vaginal cavity. Tolerance of the vaginal mucosa to irradiation is limited, so that vaginal treatments must be applied to different areas, and areas not requiring treatment must be adequately protected.

In one recent instance a patient presented herself in a rather typical late stage of the disease. A competent surgeon had removed an adenocarcinoma of the ovary. Six months later rectal bleeding and discharge had occurred. Proctoscopic examination disclosed an adenocarcinoma which involved the upper part of the rectum. Colostomy was done and exploration revealed several peritoneal implants of the neoplasm with fixation of the body of the uterus to one of these implants. The condition was inoperable. In this case, radium treatment was applied intrarectally as well as intravaginally, and with the addition of roentgen ray therapy, considerable palliation or reduction of the growth may be expected.

To summarize briefly, then, the *prognosis* in carcinoma of the ovary and tube is grave. Chances of cure in early instances of the condition by means of radical surgical intervention and postoperative irradiation are bright. Surgeons realize that any adnexal tumor, when the patient is at an age of forty years or more, should be excised because of the serious potentialities of such a tumor. In the majority of cases in which the condition is diagnosed late in its course, irradiation therapy offers valuable palliation and prolongation of life.

CARCINOMA OF THE UTERINE CERVIX

Carcinoma of the uterine cervix presents aspects entirely different from those of carcinoma of the fundus of the same organ, and treatment of the two lesions also is dissimilar.

It is interesting to consider that cancer arising in different regions of the same organ presents such radically diverse features. Carcinoma of the uterine cervix is often described as "a disease of the menopause." The average *age* of the patient in a large series of cases was forty-nine years. Examination of removed tissue under the microscope will demonstrate *epithelioma* in the majority of such cases, and the lesions will be of a high grade (grade 3 or 4) in about 80 per cent of cases. *Extension* of the growth is rapid, and invasion of the contiguous portions of the bladder and rectum occurs. *Metastasis* is common. Metastasis to lymph nodes in the broad ligaments occurs early and produces compression of the ureters with eventual uremia. Distant metastasis also may occur, especially to lungs and to bone.

Experience of the past forty years of the development of irradiation therapy has shown that radium and roentgen rays skillfully applied produce more cures of carcinoma of the cervix than does radical surgical treatment. If surgical intervention is chosen, only radical extirpation of all pelvic organs has any chance of producing a cure. The operative risk is high and the demands on the skill of the surgeon are considerable. Irradiation therapy entails practically neither risk (1 or 2 per cent at most) nor selection of cases. It can be expected

that even widespread and probably hopeless conditions may be benefited by limited irradiation treatment.

CARCINOMA OF THE UTERINE FUNDUS

Carcinoma of the uterine fundus presents a picture totally different from that just described. The average *age* of the patient who has carcinoma of the uterine fundus is about fifty-seven years. Tissue from the lesion on microscopic examination is *adenocarcinomatous* instead of *epitheliomatous*, and in most cases the tumor is of grade 1 or 2. Malignant changes occurring in the endometrium are encased within a bulky, muscular, uterine body. *Extension* through the body of the uterus is a slow process and *metastasis* is late.

In carcinoma of the body of the uterus, however, the best therapeutic approach is that of *surgical intervention* unless extension through the body of the structure and fixation have occurred. More conservative surgical measures may well be successful. Encasement of the growth within fibromuscular uterine walls and its low grade of malignancy favor surgical extirpation as the most hopeful form of attack. Usually, a postmenopausal disease, slight vaginal bleeding and discharge compel attention to the condition. Diagnosis by curettement can be established at an early stage.

Total abdominal hysterectomy, followed by the intravaginal application of radium and roentgen ray therapy, offers a favorable outlook for cure in early stages of carcinoma of the fundus when the general condition of the patient is good. The fact that the disease is found among women of a later age group than that in which cervical cancer is found precludes surgical intervention for many patients. In a large percentage of instances obesity and the presence of other constitutional disorders such as diabetes mellitus, hypertension, myocardial degeneration and so forth present serious surgical hazards. For this rather large group of patients irradiation presents little risk and offers a substantial hope of cure.

Technic of Treatment with Radium.—The technic of treatment is tedious and the treatment itself must be thorough.[2]

The objective is to secure homogeneous irradiation throughout the entire uterine and cervical canals, reinforced by treatment within the vaginal cavity. To accomplish this, tubes containing radon are placed in tandem in brass sounds. Following diagnostic curettement, the cervix is still dilated and introduction of these sounds is not difficult. At the first treatment, with the patient in the knee-chest position, the brass sound generally is introduced through the cervix to the depth of the uterine cavity. The retaining copper wire is wound in gauze packing and left in the vagina. Following a substantial dose in the deepest portion of the uterus, the second application is made to the depth of the uterine cavity and then the brass sound is withdrawn about 2 to 3 cm. and is left in place, so that a more proximal portion of the endometrium is irradiated. The number of applications in the uterine cavity depends on the size of the body of the uterus and the depth of the canal. Usually, two or three applications of the intra-uterine tandem suffice. Although the radiologist is working in the dark, so to speak, in treating in a closed cavity a cancer which cannot be visualized or delimited, adequate irradiation nevertheless can be administered by the method just described. Some overlapping of the treatment is inevitable, but is advantageous. Following the intra-uterine applications, deep cervical and vaginal treatments are administered, to be followed by roentgen-ray therapy.

Results.—The relative five-year survival rate based on the number of patients who have been operated on or who have undergone irradiation, or who have been treated by a combination of these methods, ranges from 55 to 75 per cent for patients who have had the combined method and about 50 per cent for those who have had irradiation alone. Patients in these two groups are not comparable, however, because the group which received irradiation only is composed of, usually, older patients who had more advanced lesions. Some clinics prefer to employ irradiation preoperatively and others favor the use of irradiation postoperatively.

CARCINOMA OF THE VAGINA

In carcinoma of the vagina the outlook is far more serious than that for carcinoma of the uterine fundus. Primary carcinoma of the vagina is rare, most malignant processes in this situation being metastatic. The lesion is usually *epithelioma* of grade 3 or 4. The cancer spreads rapidly by extension and soon involves the uterine cervix. *Metastasis* to deep lumbar and iliac lymph nodes occurs early.

Radium treatment usually is limited and is designed for palliation only. Plaques of radon tubes are placed against the spreading growth in the vaginal wall and, when the cervix is involved, treatment also is applied as it is for primary carcinoma of the cervix. Needles or radon seeds often are useful in the treatment of extensive infiltrating lesions of the vaginal wall. However, the vaginal wall tolerates irradiation poorly and careful protection of normal mucosa is always essential. Much scarring and contraction follow treatment. The first course of treatment should be as thorough as possible because contracture markedly limits subsequent therapy.

CARCINOMA OF THE VULVA

Carcinoma of the vulva fortunately is rare. It has been said that this lesion constitutes 4 per cent of all cancers of the genital organs in the female patient. It usually involves the labia minora and the prepuce of the clitoris, and is found among elderly patients.[3] It arises on the basis of kraurosis vulvae or leukoplakic vulvitis. These atrophic changes in the integument are not helped by radium therapy. Leukoplakia is very resistant to treatment. When carcinoma has appeared, radical surgical treatment is the most hopeful method of approach, and it should include extirpation of the inguinal lymph nodes. In the presence of extensive inoperable neoplasms treatment with radium may shrink the growth markedly and diminish discharge and bleeding.[1] The entire vulval and inguinal areas are irradiated with radium from a distance. In smaller lesions of the vulva, plaques of radium tubes may be directly applied. The ultimate prognosis in any event is poor,

although in many instances extension of the growth is slow and treatment with radium may produce improvement for a long period.

MALIGNANCY OF TUMORS OF GENITAL ORGANS ACCORDING TO PARTICULAR SITUATIONS

Carcinoma of the Uterine Fundus.—If a patient were destined to have a malignant tumor somewhere in the generative tract and could be permitted to select the particular organ to be involved, she certainly would be wise to choose the uterine fundus. She could thus enjoy about ten more years of normal healthy life than would be the case if she had chosen carcinoma of the cervix. The menopause would have passed by the time such a lesion arose. This hypothetic patient would have to be fastidious and intelligent to note and to be sufficiently concerned by the onset of a slight vaginal discharge, whether or not it was accompanied by a slight spotting of blood. She would have to be alarmed sufficiently to consult her family physician, and her fate thereafter would depend entirely on his skill and judgment. If results of the pelvic examination were essentially negative and if the cervix appeared normal on inspection, the physician would have to demand immediate diagnostic curettement. With the diagnosis fully established by this procedure, immediate surgical intervention and irradiation could accomplish a cure in the majority of instances.

Carcinoma of the Uterine Cervix.—If this hypothetic patient were allowed a second choice for situation of a malignant lesion of the genital organs, the uterine cervix would not be a bad selection. Such a decision would be based solely on the impressive advance of irradiation therapy during the past thirty years. Another factor in the choice of carcinoma of the uterine cervix is the increasing ability of diagnosticians to consider and recognize the disease while it is in a fairly early stage.

Carcinoma of the Ovaries or Fallopian Tubes.—The most hopeless malignant process for the hypothetic patient to choose would be carcinoma of the ovaries or fallopian tubes. Because of the silent nature of the lesion in these two situations, often

only conservative surgical intervention and irradiation for palliative purposes can be considered.

MALIGNANCY OF AND PROGNOSIS FOR TUMORS OF THE GENITAL ORGANS IN GENERAL

In all malignant tumors of the genital tract among women, *early diagnosis* and *immediate treatment* offer the only hopes for cure. The family physician who constantly keeps the possibility of cancer in mind and is thoroughly conversant with the early symptoms and signs of cancer is best able to save a critical situation. Either skilled surgical treatment or irradiation is indicated; or a combination of these methods may be used. Cancer is a complex problem and demands all available defenses. The "tumor clinic" or the group of physicians which offers both surgical and radiologic consultation and collaboration probably administers the best treatment to date. Each patient who has a malignant disease presents a different problem, and must be studied carefully and the treatment for her must be planned and individualized. The more care and painstaking the effort, the greater the reward in palliation and even cure.

CONCLUSIONS

The outlook for cure in cancer of the female genitalia is definitely brighter than it was even two or three decades ago. Improvement in surgical technic and the development of therapeutic radiology have definitely offered substantial hope. This year, the reported census of the American College of Surgeons listed 36,078 people as being alive up to 1940 in this country alone after having been cured of malignant lesions of all parts of the body. All had microscopically proved lesions and no evidence of malignancy could be discovered after a five-year period. This figure compares with the figure of 20,000 persons who were alive, after having been cured of cancer, in the census of 1931. The more recent figure represents a truly remarkable therapeutic accomplishment, and with continued efforts the diagnosis of cancer will cease to imply a death sentence to the average patient.

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ADVANCES IN THE TREATMENT OF CARCINOMA OF THE RECTUM

HARRY H. BOWING AND CLAUDE F. DIXON

The history of medicine is one of progress. Carcinoma of the rectum has rightfully claimed its share of the advancing knowledge of malignant neoplastic diseases of the anus, rectum and sigmoid colon. Improvement in diagnosis, treatment and prognosis advances, as a rule, very slowly; but it pushes steadily onward. It is hardly consistent with the brevity at which we are aiming, to enter at length into the subject. We have drawn heavily on the chapter on malignant neoplasms of the rectum and anus in "Practical Proctology" by Buie.[6]

The responsibility of early diagnosis of malignant lesions of the rectum and anus rests with the physician in general practice, since patients who have such lesions seldom seek aid from the specialist. Usually, ointments or suppositories have been purchased from the druggist, or some form of home treatment has been applied. The rectum is a common site of cancer. Miles said, "It is a curious fact that cancer affects the extreme ends of the alimentary tract more often than any other part of it. It has been estimated that of all alimentary canal cancers one-third occur in the oral cavity, less than a third in the esophagus, stomach, small intestine, and large intestine put together, and rather more than a third in the rectum."[18]

INCIDENCE, LOCATION AND TYPE OF RECTAL CANCER

It would be difficult to prove that cancer of the rectum is on the increase. The laity and the profession are alert to the probable presence of cancer and as a result more and more

patients are seen early in the course of the disease. However, the majority of patients are seen either in the borderline or inoperable stage of the disease.

Buie reviewed the proctoscopic records of 2723 cases of malignancy of the rectum seen at the Mayo Clinic in the decade 1925 to 1934. Sixty-five per cent of the patients were males and 35 per cent were females. Eighty-nine per cent were more than forty years of age. The average age was fifty-five years. Seven patients were less than twenty years of age. One of every nine patients was less than forty years of age and, furthermore, one of every forty patients was less than thirty years old. Eighty-seven per cent of the patients had noticed the passage of blood and in 66 per cent of the cases pain was a permanent feature.

In the study of a large series of cases, certain findings naturally can be classed as *avoidable delays*. For example, in 521 cases surgical operations had been performed for conditions that could be considered alien to the malignant lesion. Furthermore, in 1073 cases the patients had been attended by physicians before they registered at the Clinic, and in 784 cases attention probably had been received when the patients had symptoms that were caused by the malignant lesions. "Every cause for failure to make the proper diagnosis in cases of rectal carcinoma should be sought out so that all possible means can be employed to reduce the error." [6]

The *duration of the chief complaint* or illness was less than one year in 61 per cent, and illness was less than six months in approximately 75 per cent, of the cases.

Proctoscopic examination showed that the lesion was in the rectum, rectosigmoid, or sigmoid colon in 93 per cent of the cases, and in the anus in 7 per cent of the cases. Some of the anal lesions were secondary to a rectal growth. A further subdivision was made. In 60 per cent of cases the lesions were in the upper half of the rectum; in 33 per cent of the cases they were in the lower part of the rectum and anus, and in 7 per cent of cases they were in the rectosigmoid or in the sigmoid colon.

Data are also presented to show the relation of the lesion to the *circumference* of the bowel. Thirty-nine per cent of the lesions were annular, 23 per cent were limited to the lateral wall, 21 per cent were limited to the anterior wall, and 16 per cent were limited to the posterior wall.

Miles said: "It may be inferred that, in the ampulla of the rectum at all events, the involvement of the circumference of the bowel is a comparatively slow process, and that by the time three-fourths of the circumference has been involved the growth has been in existence for about eighteen months. The extent, therefore, of the circumferential involvement may be taken as an index of the duration of the lesions."[10] In commenting on this statement Buie said: "If this belief is borne out, it will be found that in this series, more than a third of the growths had existed for more than eighteen months prior to the time that the patients were admitted to the clinic. . . . It is further evidence of the probability that carcinoma of the rectum may become extensive before the patient becomes aware of it."[6]

Some degree of interference with the passage of feces was noted in 58 per cent of the cases. The amount of *obstruction* was graded 1 to 4. In 45 per cent of these cases the obstruction was grade 1, in 39 per cent of the cases it was grade 2, in 15 per cent of cases it was grade 3, and in 1 per cent of cases it was grade 4. The *size* of the lesions was tabulated. They were small, that is, 3 cm. or less in diameter in 5 per cent of the cases; they were of moderate size, that is 3 to 6 cm. in diameter, in 19 per cent of cases; they were large, more than 6 cm. in diameter, in 65 per cent of cases, and they were huge, that is, they could not be outlined and usually formed part of an extensive fixed pelvic mass, in 11 per cent of cases. The *mobility* of the lesions was studied: in 32 per cent of cases the lesions were movable, in 33 per cent of cases they were attached or had limited motion, and in 34 per cent of the cases they were fixed.

The *type of lesion* is of interest and biopsy is a routine procedure at the Clinic. Adenocarcinomas were found in 94

per cent of the cases, epitheliomas were found in 3 per cent, colloid carcinomas were found in 1 per cent, melano-epitheliomas were found in 1 per cent, and lymphosarcomas were found in 1 per cent.

The *grade of malignancy*, according to Broders'[5] method, was as follows: grade 1 in 45 per cent, grade 2 in 39 per cent, grade 3 in 15 per cent, and grade 4 in 1 per cent of cases. In 84 per cent of the cases the grade of malignancy was rather low, that is, 1 or 2, but in 16 per cent of cases the grade of malignancy was 3 or 4.

Buie also said that "The average patient who comes to the Mayo Clinic with a rectal carcinoma is a man, about fifty-five years of age, who has been sick for eight to ten months. His illness usually has been characterized by rectal bleeding, a sense of incomplete evacuation, and discharges of bloody mucus instead of feces. His discomfort usually is rather obscure but is more noticeable 'up inside' the rectum and in the lower part of the abdomen. The growth is found in the upper half of the rectum and often is annular and large. It is almost always an adenocarcinoma of grade 1 or 2, and produces a moderate degree of obstruction." Some degree of obstruction was noted in 58 per cent of the cases. In 78 per cent of the cases the lesions were estimated to be large growths. In 68 per cent of the cases the growths were adherent or fixed.

PATHOLOGIC CHANGES

From the standpoint of therapy, the gross characteristics of carcinomas of the rectum are important. According to Miles, all carcinomas of the rectum are adenocarcinomas but they are classified clinically into three groups: (1) papilliferous carcinomas, (2) adenoid carcinomas, and (3) colloid or mucoid carcinomas.

A *papilliferous* carcinoma resembles a simple papilloma (Fig. 67). The base of the lesion penetrates the muscularis mucosae. Irregular proliferation of the epithelial elements occurs. The growth is exuberant and the neoplasm fills the lumen of the bowel.

An *adenoid* carcinoma is a sessile growth that infiltrates the mucosa and submucosa. It grows in all directions and soon infiltrates the muscular layer. It is prone to undergo ulceration and readily involves the lymph nodes (Fig. 68).

A *colloid* carcinoma represents a mucoid degenerative change in the epithelial elements and the connective tissue of a papilliferous or adenoid carcinoma.

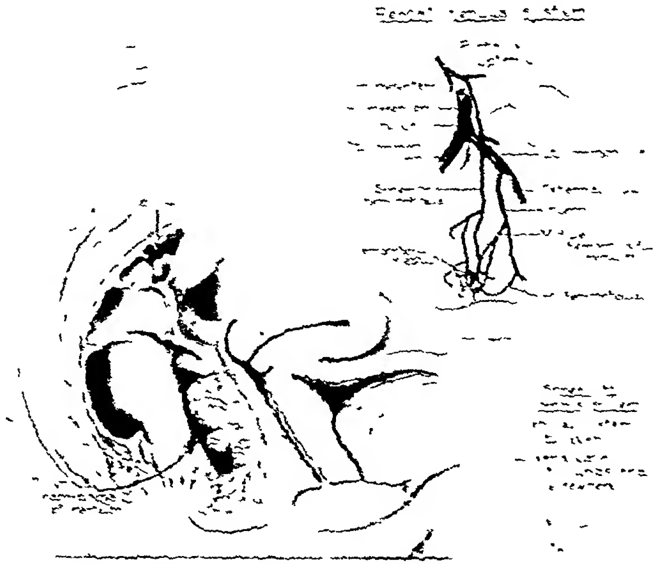

Fig. 67.—Papilliferous carcinoma of the rectum involving the anterior rectal wall of a female patient, sagittal section showing the rectal venous system and portal vein.

Adenomas may undergo a malignant change. These tumors are of two types: (1) *pedicled* or sessile adenomas, and (2) *villous* adenomas. Pedicled or sessile adenomas have soft, fine lobulations and are devoid of induration. A villous adenoma is a soft exuberant tumor that feels like a mass of redundant mucous membrane. The borders are difficult to outline by palpation.

The Spread of Malignant Disease of the Rectum.—This is very important. According to Miles,[18] the spread may

occur in any of three distinct ways: (1) by *direct extension* through continuity of tissue; (2) by way of the *venous system*, and (3) by means of the *lymphatic system.* The direct spread may take place on the mucous surface of the bowel progressively from its entire margin and through the thickness of the bowel wall. The rectal veins belong to the portal system (Fig 67). Cancer cells may penetrate into the interior of small veins, become detached and be carried straight to the liver.

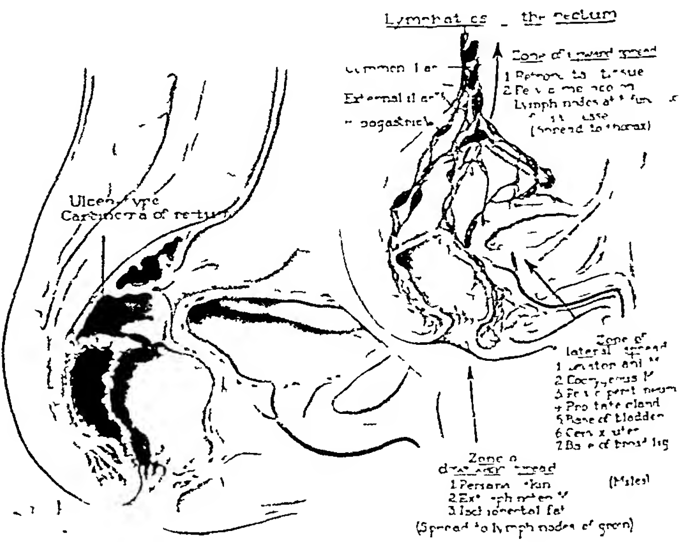

Fig 68—Adenoid carcinoma and ulceration involving the posterior rectal wall of a male patient, sagittal section showing lymphatics of the rectum and zones of spread of the lesion.

The malignant embolism usually is situated in the middle of the right lobe.

The lymphatic system is infinitely most important in the spread of cancer cells. There are three groups of lymphatics: *intramural, intermediary,* and *extramural.* The intramural lymphatics are contained in the wall of the rectum in two networks. One network is in the submucous tissue and the other is between the muscular layers. The networks communicate freely by means of short radial channels. The intermediary

system consists of a subserous network of lymphatics in the portion of the rectum covered by peritoneum and a lymph sinus situated between the external muscular coat and the perirectal fat in that part of the rectum devoid of a peritoneal investment. The extramural lymphatic system is the most important and may be considered in three divisions which are intercommunicating. The structures in the zone of downward spread are the perianal skin, the ischiorectal fat and the external sphincter muscle. The structures in the zone of lateral spread are the levator ani muscles, the coccygei muscles, the pelvic peritoneum, the prostate gland, the base of the bladder, the uterine cervix, the base of the left broad ligament, and the internal iliac lymph nodes. The structures in the zone of upward spread are the retrorectal lymph nodes, the pelvic mesocolon, the paracolic lymph nodes, the lymph nodes at the bifurcation of the left common iliac artery, and the median lumbar (aortic) lymph nodes. The majority of the different lymphatics of the intramural system pass through or terminate in this zone. It is therefore the zone of the principal paths by which spread from the primary growth occurs. Regardless of an early stage of development, Miles found *metastases* scattered throughout this zone in practically all cases (Fig. 68).

ETIOLOGY

Robertson[20] said that most students of cancer "have thus been forced to regard the disease as due to some intrinsic derangement of the growth mechanism of certain cells of the body, whereby these cells themselves attain such independence of reproduction that they assume some of the characters of a parasite or in fact become real parasites. The nature or cause of this change in the cells is at present almost wholly unknown. . . . Cancer then does not come from 'stimulation of growth,' as is so frequently asserted, but because the normal mechanism for governing orderly growth is disturbed. This mechanism must be inhibitory."

W. J. Mayo[17] said: "Chronic irritation, whether the result of mechanical, chemical, or infectious agencies, is the most

important of all these precancerous conditions with which we are acquainted and it is undoubtedly the most potent influence in the development of the disease following congenital lesions and trauma."

C. H. Mayo[16] said: "The essentials of cancer are uncontrolled hyperplasia developed in repair types of nucleated cells; . . . (it) grows most favorably in acid fields." He also said that nearly a third of the cancers that affect man are found in situations where acidity is constant and high, for example, in the stomach. The uterine cervix, urinary bladder and mouth come in contact with acid secretions but the reaction of the contents of the small intestine is alkaline. Of 1882 cancers of the intestinal tract for which operation was performed at the clinic between 1897 and 1913, only twenty-two were found in the small intestine.

Precancerous Polyp Formation.—Buie expressed the opinion that "it is justifiable to support the hypothesis that malignant growths of the colon often develop from polypoid lesions which either give no evidence of malignancy at the outset or possess early the mildest evidence of malignant change. That adenomatous polyps, of whatever type or dimension, should be dealt with as precancerous growths, does not admit of denial."

Robertson[20] said: "Most cancers of the colon begin as polypoid growths of the mucosa. The smaller ones and those with a long pedicle have the epithelium arranged in an orderly, normal manner. Sooner or later, particularly early in the sessile types, certain epithelial cells begin to proliferate more rapidly, the chromatin of their nuclei becomes denser and more irregularly distributed. . . . Mitotic figures increase in number." Gradually more and more gland groups are involved and the growth of cells breaks through the basement membrane and begins to invade the stroma of the mucosa and submucosa. Then the growth is a cancer.

We have reviewed the work of Fitzgibbon and Rankin[11] on polyps of the large bowel. They classified the polyps in three major groups based on characteristic structural varia-

tions. Each group not only presents pathologic unity, but follows a definite predictable clinical course. The polyps of *group 1* are nodular pedunculated tumors. The epithelium of

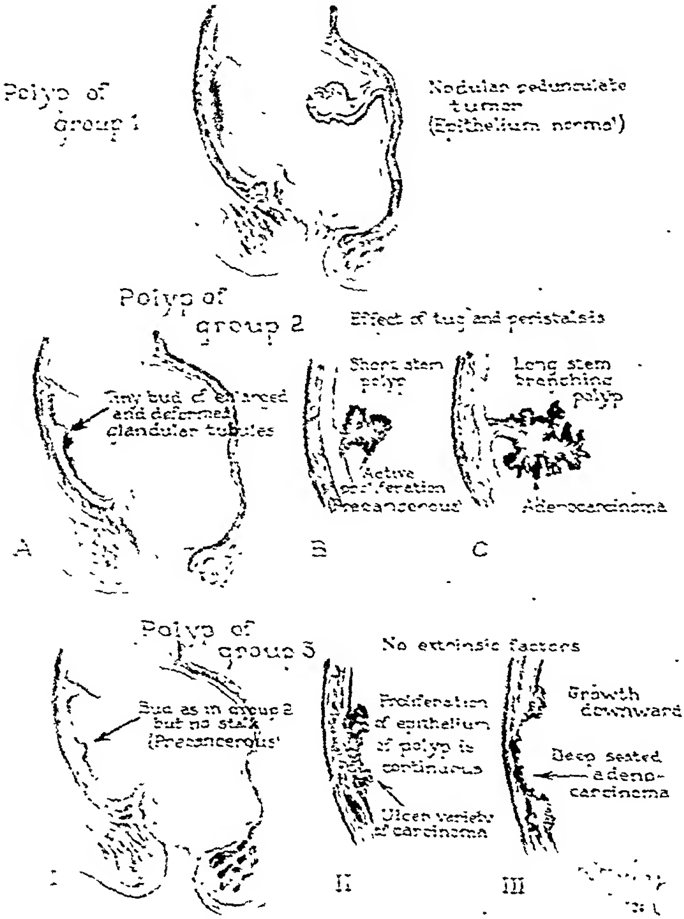

Fig. 69.—Artist's attempt to visualize the gross characteristics of the three groups of polyps described by Fitzgibbon and Rankin.

the surface and crypts remains entirely normal. Polyps of *group 2* are invariably pedunculated, they may be small pea-sized or large egg-sized tumors or they may be flattened

button-sized sessile tumors. The tug of the epithelial proliferation and peristaltic action on the muscularis mucosae and the areolar tissues of the submucosa form a rudimentary stalk that eventually results in a tree-like formation. This group embraces most of the polyps found in the large intestine. There is no sharp line of separation between the polyps of groups 2 and 3. The polyps of *group 3* start in an overgrowth of glandular tubules in the mucosa; the tubules enlarge and elongate. They may occur in the trough and on the crest of the mucosal folds. They may attain the size of a split pea. There is no organoid formation. The elementary epithelium proliferates so rapidly that the nodule approaches cancerous change before enlargement occurs. Cells of these epithelial complexes cannot be distinguished morphologically from those seen in outright carcinoma. The artist has attempted to visualize the gross characteristics of the three groups of polyps (Fig. 69).

The polyps of group 1 are benign, those of group 2 tend inevitably to undergo malignant change, and those of group 3 are immediate precancerous formations. Fitzgibbon and Rankin said that it is an "extremely plausible contention that the histogenesis of carcinoma of the colon is mediated through precancerous polyp formation and not otherwise." [11]

Since adenocarcinomas predominate in the terminal part of the colon, some authors claim that all carcinomas of the rectum originate in the crypts or glands of Lieberkühn. Buie said: "Their origin is supposed to be owing to a power which they possess to produce either secretory or protective epithelium. Such power resides in the regenerative cells of glandular epithelium." [6]

DIAGNOSIS

The *history*, *digital* and *endoscopic examinations* and *biopsy* are essential in the diagnosis and management of cancer of the rectum. Buie said: "With the exception of menstruation, there is no instance in which discharge of blood from a hidden viscus may not mean trouble." This complaint deserves the utmost and painstaking consideration. The digital

examination determines the site of the neoplasm. As a rule, the presence of a characteristic carcinomatous infiltration in the lesion assures the examiner of the presence of cancer. A malignant lesion is not painful on palpation, except when the downward spread involves the dentate area or when the lesion primarily involves the anus. The proctoscopic examination determines the gross visual characteristics of the lesion, its size and mobility, the extent of local infiltration, the distance from the anal margin and the extent of involvement. A representative bit of tissue is removed for microscopic study and grading of the malignancy. Careful inspection of the proctoscopic field for a malignant neoplasm reveals that the lesion is usually single, the edges are circumscribed, and the mucosal margins are normal. As a rule, infiltrating lesions are associated with some degree of ulceration. The differential diagnosis must rule out the presence of primary carcinoma of the ovary, uterus, adenomyomas of the endometrium or prostate gland as well as carcinoma of distant structures metastasizing to the pelvis. Papillomatous growths of the colon that have dropped into the rectum may simulate primary rectal carcinoma. The general consideration of the patient is of great importance, especially when operation is planned. The age of the patient and the presence of obesity, arteriosclerosis, disease of the lungs, heart and kidney add greatly to the risk of radical operation.

TREATMENT

The treatment of rectal carcinoma may be of two types: *curative* and *palliative*. The procedures employed are operation, radium therapy, roentgen therapy, fulguration and electrocoagulation. These procedures may be employed singly or in various combinations to meet the individual requirements of the case. The data presented clearly indicate that no one procedure or standardized method can be employed in all cases.

SURGICAL MANAGEMENT

The surgical procedures that are employed in cases of carcinoma have been classified as follows by Miles: (1) excision

of the rectum undertaken from the perineum alone; (2) perineal resection; (3) resection through the vagina, and (4) combined abdominal and perineal excision, including the abdomino-anal operation and the radical abdominoperineal operation. The use of the first procedure is restricted to cases in which the lesion is situated in the lower part of the rectum or in the anus. Perineal resection includes resection of the bowel and an end-to-end anastomosis. Resection through the vagina is a restricted procedure, as is the abdominoperineal operation.

In considering the *criteria for operability* Miles[18] said that uninvolved mucosa must be present above the growth, that one should be able to reach the growth with the examining finger and that the growth may be situated in any part of the rectum provided it is movable. Miles reported that the lesions were operable in 172, or 23.3 per cent, of 587 cases. He felt rather certain that this low rate would be the same in the experience of most surgeons of his country. He cited continental authorities: Boas, found 19 per cent patients suitable for operation; Witzel, 25 per cent; Czerny, 71 per cent; Bergmann, 80 per cent, and Eiselberg, 65 per cent. Priestley and one of us (Dixon[10]) said that "the experience and ability of the surgeon and his familiarity with this field should influence the decision." In a discussion of carcinoma of the rectum one of us (Dixon[7]) said that in 65 per cent of the cases of carcinoma of the rectum the lesion was found to be inoperable when the patients came to the Clinic. Broders'[5] study of the relation of the grade of the cancer to metastasis and prognosis has added much to our knowledge of malignant lesions. Broders found evidence of metastasis in 260, or 46.4 per cent, of 560 cases of carcinoma of the rectum. Metastasis was found in 26.3 per cent of the eighty-two cases in which the lesion was grade 1, in 44.1 per cent of the 290 cases in which the lesion was grade 2, in 56.2 per cent of the 137 cases in which the lesion was grade 3 and in 64.7 per cent of the fifty-one cases in which the lesion was grade 4.

One of us (Dixon) has said that the following operations

may be employed in cases of carcinoma of the rectum or rectosigmoid: (1) local excision, (2) posterior resection and the formation of a sacral anus, (3) colostomy and posterior resection (one or two stages), (4) combined abdominoperineal resection in two stages, and (5) combined abdominoperineal resection in one stage, as advocated by Miles.[18] *Preoperative preparation* of the patient has reduced the surgical risk. Three to five days of preoperative hospitalization is desirable. Seldom is there complete obstruction in cases of rectal carcinoma, but some degree of obstruction usually exists. An effort should be made to clean the bowel by mild saline cathartics and warm saline irrigations. The diet should be high in carbohydrates. A generous supply of fluids is desirable. If a pronounced anemia exists, one or two transfusions will add greatly to the patient's resistance. The value of vaccine in an attempt to prevent peritonitis following colonic operation has been considered (Dixon[8]), who said that in the past seven years more than 2500 intraperitoneal injections of vaccine have been administered at the Clinic as a preventive measure, and as a result the mortality from peritonitis following intestinal operations has decreased 66 per cent.

The selection of an *anesthetic agent* is ever important. A sacral block is satisfactory for perineal work. Spinal anesthesia affords complete relaxation and ablation of peristalsis for several hours, it is a desirable anesthetic in cases in which pulmonary complications are present or the patient is obese but it is less desirable in cases in which the patients are in the advanced years of life and have hypertension, arteriosclerosis, and nervous instability. Inhalation anesthesia (nitrous oxide, ethylene, ether) is a fine method in many cases.

Space does not permit a discussion of the actual *operative technics*. Briefly, all tumors of the colon are heavily infected; therefore, handling of the growth must be reduced to a minimum. Before mobilization of any lesion of the rectosigmoid or sigmoid colon, the left ureter should be identified. An adequate blood supply must be maintained. One should look for pulsations in the blood vessels supplying the affected segment

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Space does not permit a discussion of the actual *operative technics*. Briefly, all tumors of the colon are heavily infected; therefore, handling of the growth must be reduced to a minimum. Before mobilization of any lesion of the rectosigmoid or sigmoid colon, the left ureter should be identified. An adequate blood supply must be maintained. One should look for pulsations in the blood vessels supplying the affected segment

of bowel. Accurate peritonization of all raw surfaces is important.[10]

Postoperative treatment also is important. The abdomen must be kept quiet. Morphine may be used liberally for the first forty-eight hours. No fluids should be given by mouth until gas has been expelled, which usually is at the end of forty-eight to sixty hours. The mouth should be kept moist and clean to prevent parotitis. One should maintain a fluid balance with hypodermoclysis of a physiologic solution of sodium chloride and occasionally by the intravenous injection of 5 or 10 per cent solution of d-glucose. Transfusions of blood are of value in those cases in which the patients are having difficult postoperative days. Ileus usually responds to the use of hot stupes and the administration of posterior pituitary extract or physostigmine. Enterostomy may be necessary in some cases.

Most patients, when told that a permanent *colonic stoma* is essential, are completely demoralized. It was to be expected, eventually, that surgeons would select patients with great care for colostomy. The radical combined abdominoperineal operation removes all of the colon and rectum distal to the point where the colon is divided. This procedure requires a permanent colonic stoma. If the surgeon explains carefully to the patients that an artificial anus can be cared for properly, through their co-operation and by the regulation of diet, they will accept colostomy with considerable resignation and co-operation. Fourteen per cent of rectal carcinomas occur in the region of the rectosigmoid. In the past five years, in the removal of lesions proximal to the rectosigmoid, one of us (Dixon) has performed an operation which preserves all or part of the rectum and does not require a permanent colonic stoma. An end-to-end anastomosis is done.

The *results* of the surgical management of colonic carcinoma have been described by one of us (Dixon), who reported 753 cases of carcinoma of the colon. In the 566 cases in which the lesion was in the left half of the colon or in the rectum, 270, or 47.7 per cent, of the patients were alive five

years after operation. "The experiences of those who are treating colonic carcinoma seem to be ample justification for the optimism that prevails concerning its curability. Furthermore, with constantly improving methods of treatment, it has become possible to give relief to patients when the disease is in the stage which was formerly considered to be hopeless."[9]

RADIUM THERAPY

Radium therapy has a definite place in some cases of carcinoma of the rectum. Its use is *indicated* in the following groups of cases: (1) a selected group of cases in which the lesions are operable, namely, cases in which the patients refuse to undergo an operation or cases in which the patients are so old that an operation is not desirable; (2) cases in which the lesions are inoperable, and (3) cases in which the lesion has recurred after an operation.

In the treatment of carcinomas of the rectum with radium, Gordon-Watson and Dukes[12] said that adenocarcinoma, although resistant, is not insensitive to radiation and that "with perhaps the exception of the oesophagus, no branch of radium therapy which is practiced today presents greater difficulty of access. Many other difficulties arise, especially with regard to uniform distribution, lymphatic spread, sepsis, bladder complications, and adequate observation of the progress of the case, and it is not surprising that some workers with much experience of radium have abandoned the pursuit and are content to write off carcinoma of the rectum as radioresistant."

In the early years of radiation therapy at the Mayo Clinic, the extensive or inoperable and recurring lesions were treated. As a rule, *palliation* occurred and in some cases the duration of this effect was many years. In a few of these cases operation was performed later and active carcinoma could not be demonstrated by microscopic study of the excised specimen. In nearly all cases the tendency to bleed, the frequent passage of mucous rectal discharges, the odor, and pain were greatly reduced or disappeared entirely. Other complications, for example involvement of the bladder and vesicorectal fistulas,

were either avoided or delayed. In other words, the reduction in activity and size of the rectal carcinoma was of great value in the medical management of the patients.

Very early in our experience we were of the opinion that cancer of the rectum was radiosensitive since the lesions are chiefly adenocarcinomas. MacCarty[14] had shown, by the histologic study of cancer of the breast, stomach and rectum, that *differentiation, fibrosis, lymphocytic infiltration* and *hyalinization* favorably influence the longevity of patients following surgical removal of the cancer. This study was further amplified by MacCarty and Kehrer[15] in a report of 102 cases of cancer of the rectum. They said that "with all four factors present in combination, the average length of postoperative life is 196 per cent greater than if none of these factors are present," and further concluded that "it may be stated that from this series of observations, lymphocytic infiltration, cellular differentiation, fibrosis and hyalinization seem to play a part in prolonging the postoperative length of life." In 1925 one of us (Bowing[2]) reported forty-eight cases in which cancer of the rectum was treated by radium and operation. The intervals between radium therapy and operation varied from a few weeks to many months. The tumor tissue was sectioned and Broders estimated the presence and amount of lymphocytic infiltration, cellular differentiation, fibrosis and hyalinization in the tissue that had been treated with radium. Briefly, the treated tissues not only contained all these factors but were found to contain in excess amounts those factors, which are related to longevity. The post-radium treatment life of this group of patients was slightly greater than the untreated group previously reported. Evidently these processes were stimulated or accelerated by the radium therapy. This finding furnished further encouragement to the radium therapist and to all concerned.

The treatment may be discussed under three headings: (1) preoperative, (2) postoperative, and (3) nonoperative.

Preoperative Treatment.—Today, we are convinced that the best method is to treat the patient from the standpoint of

a "cure" with radium and then allow a sufficient time between the application and the operation. At least two months, and probably three months or more, should be allowed to elapse before surgical intervention is instituted. In other words, the ultimate response to radium should be allowed to occur. Cases can be cited in which the site of the primary cancer was sterilized and a conservative type of surgical intervention was carried out.[7, 10]

Postoperative Treatment.—This is a limited method of treatment. For immediate postoperative treatment the perineal wound can be left open or a drainage tube can be inserted for the introduction of the radium tubes. The universal tube that contains 50 mg. of radium sulfate (element), which is filtered, with 0.5 mm. silver and 1 mm. brass, is the applicator of choice. In cases of recurrent carcinoma the mass may be excised and radium needles may be introduced into the walls of the wound. Radon seeds also may be placed in the field of operation. In some cases of recurrent carcinoma a sinus may be present in the posterior wound. This may be curetted or enlarged and radium tubes may be introduced. In cases in which women have a recurring pelvis mass, it is usually possible to apply the vaginal pack and radon seeds may be inserted into the sacral mass through the posterior and lateral vaginal walls. In some cases of very painful recurring lesions we have noted marked and lasting relief from pain. The discharge is favorably influenced and, by checking the local growth, involvement of the bladder may be arrested.

In another group of cases in which the recurrent lesions are so extensive that further operation or the application of radium by the puncture method is contraindicated, large *radium packs* may be applied to the sacral and perineal fields. Four universal tubes, each containing 50 mg. of radium sulfate (element), which is filtered with 0.5 mm. of silver, 1 mm. of brass and the lead jacket, the wall of which is 2 mm. thick, are strapped on the surface of a balsa wood block. The thickness is 5 cm. and the base measures about 8 cm. square. The time

of application is twenty hours for each field. The number of fields depends upon the extent of the recurrence.

Parotitis[10] is a rather frequent complication in cases in which operations are performed on the colon. The treatment with radium has been rather satisfactory. As soon as the diagnosis is made the treatment should be applied. The technic is as follows: The region of tenderness or infiltration is mapped out into squares measuring about 4 by 4 cm. To each square an applicator is applied for six to eight hours. The universal tube, which was previously described, and which contains 50 mc. of radon, is strapped onto the surface of a balsa wood block, the thickness of which is 2.5 cm. and the base of which is 3 cm. square. The number of squares should be sufficient to cover the field of involvement and extend well beyond. From two to four blocks are applied at one time for a period of eight hours and the application is continued until all squares are covered. Following an interval of forty-eight hours, a noticeable reduction in the parotitis occurs, but if it does not occur following a suitable interval, a second series of applications should be employed.

Nonoperative Treatment.—In most of the cases in which radium is employed the lesion is *inoperable* or there are extensive local lesions. Much palliation can be expected, as previously mentioned. Gordon-Watson and Dukes[12] reported that inoperable lesions have been made operable. We can substantiate this statement, as in some cases in which inoperable lesions were irradiated the patients later underwent an operation and microscopic examination of the excised tissue did not show any evidence of active carcinoma. With the aid of the proctoscope, tubes are placed in the sinus of an annular lesion or on the surface of flat tabular infiltrations. In some of these cases colostomy was not performed. Instead, the patients were instructed regarding a diet that is low in residue and high in calories and vitamins. They were further instructed to irrigate the rectum with warm saline solutions or a low oil enema at bedtime. When necessary, a small amount of liquid

petrolatum or a mild saline cathartic may be administered orally.

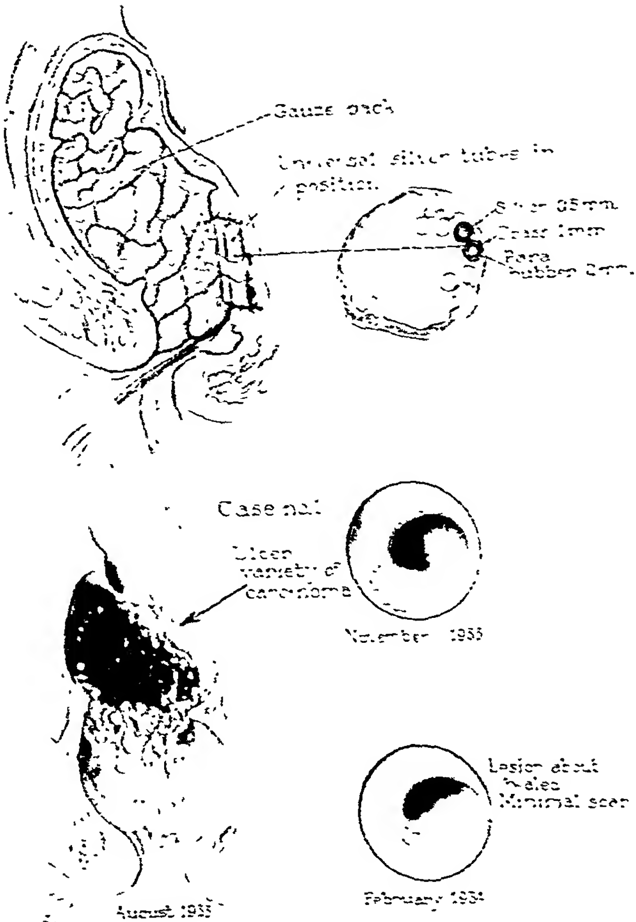

Fig. 70.—Conservative radium treatment for an ulcerative adenoid carcinoma of the rectum; tubes are held in place with gauze packing.

In cases of annular lesions in which *colostomy* has been performed, intensive radium therapy is used. The universal tube containing 30 mg. of radium sulfate (element) which is

of application is twenty hours for each field. The number of fields depends upon the extent of the recurrence.

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Conservative Method.—The radium applicators employed in the conservative method are the *universal tubes* containing radon or radium sulfate (element), which is filtered through 0.5 mm. of silver, 1 mm. of brass, and 2 mm. of Para rubber. The amount in each tube may vary from 20 to 50 mc. or mg. each. One or two tubes may be applied at one time (Fig. 70). The dose for each region varies from 40 to 90 mc. or mg. hours per square centimeter. The number of regions to be treated depends upon the extent of the surface of the cancer. Two regions a day can be treated until the entire surface of the lesion has been covered. In the female patient *vaginal packs* are placed along the posterior vaginal wall in the region of the rectal infiltration. The vaginal applicator usually contains the universal tube of 50 mg. of radium sulfate (element), the walls of which are composed of 0.5 mm. of silver and 1 mm. of brass. This is placed in a lead jacket, the walls of which are 2 mm. thick; then the tube and the lead jacket are placed in a spool-like rubber jacket, the walls of which are 1 cm. thick. The time of one application is fourteen hours. From one to three or four applications are required, depending upon the size of the vaginal cavity and the region of rectal infiltration to be covered. Treatment may be applied daily. This surface method can be applied with very little or no risk. All radium treatments in the rectum are applied with the patient inverted and with the aid of an endoscope. Gauze packing is used to hold the applicator in place and to protect as much as possible the uninvolved wall of the rectum and vagina.

Radical Method.—In the radical method of radium therapy, various needles containing radium sulfate (element) or gold radon seeds are employed (Fig. 71). The tissues must naturally be punctured and this adds a definite risk. This method is decidedly more limited than is the conservative method previously described.

Results.—Fricke and one of us (Bowing[4]) reviewed 500 cases of primary rectal carcinoma in which irradiation therapy was employed. The patients were treated early in our experience, that is, from 1915 to 1931, inclusive. In more than half

filtered through brass and silver as previously described, is placed in tandem position in the sinus until the entire length

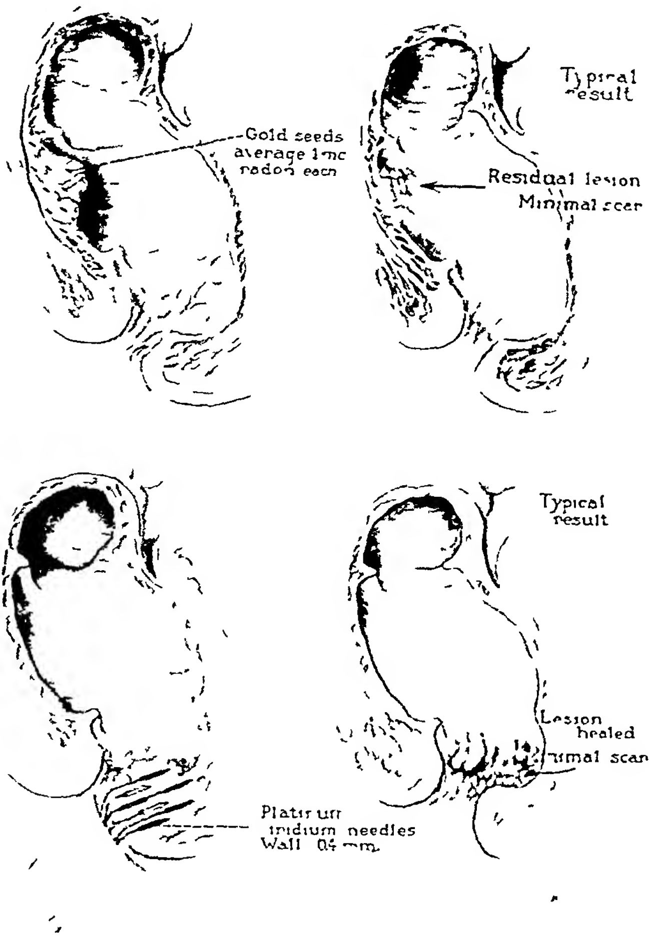

Fig 71—*Papilliferous carcinoma of the middle portion and lower portion* of the rectum being treated by the radical radium method, the lesion in the middle portion is being treated with interstitial gold radon seeds and the lesion in the lower portion is being treated with platinum iridium needles containing 1 mg radium sulfate (element)

of the lesion is treated; ten to fourteen hours per tube is applied.

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of the cases the lesions were classed as inoperable. Of the 500 patients, 108, or 23 per cent, lived more than three years after treatment, sixty-three, or 13 per cent, lived more than five years, and twenty-two, or 5 per cent, lived ten or more years. Of the forty-two patients who received radium therapy before operation, eight, or 19 per cent, lived more than three years, seven, or 16.6 per cent, lived more than five years, and four, or 9.5 per cent, lived more than ten years after they were dismissed from the Clinic. Of the 153 patients who received radium therapy after operation, twenty, or 13 per cent, lived more than three years, twenty-seven, or 17.7 per cent, lived more than five years, and eleven, or 7.2 per cent, lived more than ten years. Of the 286 patients who were treated only by irradiation therapy, sixteen, or 6 per cent, lived three or more years after the treatment, five, or 1.8 per cent, lived more than five years, and five, or 1.8 per cent, lived ten or more years. Of the 481 patients who were treated with irradiation, either alone or combined with operation, forty-four, or 9.6 per cent, lived three or more years after the completion of the treatment, thirty-nine, or 8.5 per cent, lived five or more years, and twenty, or 4.3 per cent, lived ten or more years.

ROENTGEN THERAPY

Binkley[1] states that treatment by irradiation is not only a palliative measure, but it is also a method capable of producing clinical cures in properly selected cases in which the lesion is operable but that it should not be used as a routine procedure. The first step is *external* irradiation in the favorable group of cases. The usual factors for such treatment are 200 kv., 30 ma., 70 cm. target-skin distance, a filter of 0.5 mm. of copper and 2 mm. of aluminum, and a portal of 14 by 10 cm. Eight hundred and fifty roentgen units at one time or a divided dose may be employed. To supplement this sublethal dosage, *interstitial* therapy with gold radon seeds may be employed. The interval between external and intratumoral treatment is about a fortnight. In cases in which the disease is more advanced, the technic is about the same except that

colostomy is often necessary. For *palliative* treatment, external therapy is used alone. Six portals of high voltage roentgen rays, employing 3/4 to 1 erythema dose to each portal, may be given in one or two applications, and may be repeated at short intervals. Sublethal doses of interstitial therapy (gold seeds) may be used in some cases. Binkley said that the 4 gm. radium pack may be used alone or in combination with roentgen rays for external irradiation. Colostomy is required in about 50 per cent of the cases.

Preoperative irradiation therapy may consist of external irradiation used alone or together with gold radon seeds, especially in cases in which the growth is situated below the reflection of the pelvic peritoneum. Gordon-Watson and Dukes[12] said that the cases which they had observed are too few to warrant a definite conclusion but expressed the opinion that "deep *x*-ray therapy seems to be of more use before than after radium," and that the use of deep roentgen therapy after the use of radium did not produce any noticeable improvement.

At the clinic we have used roentgen rays chiefly as a *postoperative* procedure. Roentgen therapy may be given immediately after operation or at a later date, that is, in the advent of a recurrence. Treatment is usually applied to four to seven pelvic fields, at the rate of one field daily, each being treated with the following factors: 200 kv., filtered through 0.75 mm. of copper and 1 mm. of aluminum, at a focal-skin distance of 50 cm., with 15 milliamperes, for thirty minutes, or approximately 600 r measured in air. We have tried fractional irradiation in a few cases, but the results at present are inconclusive.

For the *relief of pain* in cases in which the lesions are very large, a suberythema dose is employed and the results are good or fair.

SURGICAL DIATHERMY

Fulguration.—Buie[5] has had a unique and wide experience with fulguration in the treatment of precancerous and cancerous lesions of the rectum. He employs the monopolar

type of Oudin current to burn or char the tissues. The cases, which are selected carefully, are composed chiefly of those in which *papilliferous growths* are situated on the posterior rectal wall below the reflection of the pelvic peritoneum. Naturally, this is a small group representing about 5 to 10 per cent of cases of rectal cancer. He has more than 100 cases in his series but the time interval is too short for statistical study. At the time of the fulguration or immediately afterward, topical or conservative radium treatment (previously described)

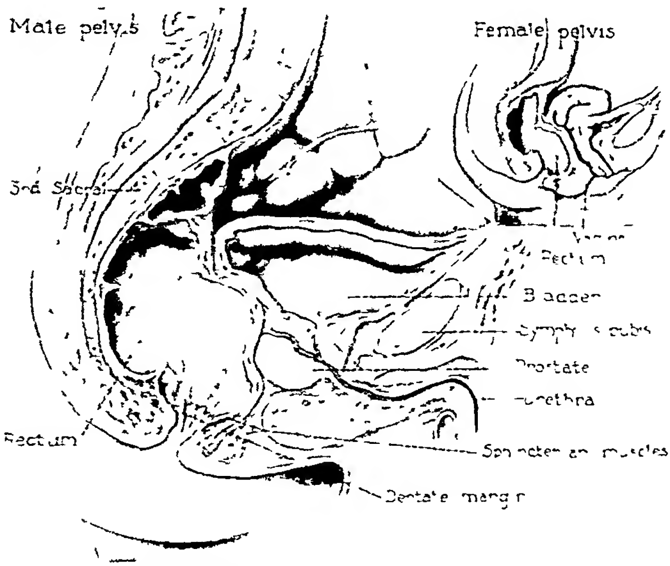

Fig 72.—Sagittal section of the normal pelvis

is applied to the charred area to prevent hemorrhage. This was a troublesome complication until radium therapy was tried. So far, the results of the combined treatment have been very satisfactory.

Fulguration of *polypoid lesions* of the colon, within that region which may be explored with the proctoscope, can be employed. The co-operation of the patient is necessary. General anesthesia is contraindicated, but large lesions necessitating unusual exposure and a large speculum require anesthesia.

The patient should be placed in the inverted position; if this is done intestinal loops are less likely to remain in the region of the lesion. If the lesions are small and pedunculate, they may be fulgurated regardless of their position in the intestine. Lesions in the mobile portion of bowel must be treated cautiously. Lesions on the posterior wall respond very satisfactorily to treatment. Lesions on the anterior wall respond less satisfactorily on account of neighboring anatomic structures (Fig. 72).

Small rectal lesions do not require hospitalization except when they are situated in the mobile portion. Whether the lesion is large or small the patient should be kept in bed. *Complications* are perforation and hemorrhage. The application of radium to the base of a lesion immediately after fulguration and the treatment carried to completion in the next few days have markedly reduced the tendency of hemorrhage. Observation after treatment varies within broad limits. Fractional treatment may be necessary. Patients who have a simple polyp may be dismissed immediately following fulguration. Polyps involving the entire rectum may require several years for the treatment and observation.

Kelly and Ward[15] reported their experience with electrothermic methods in the treatment of diseases of the rectum and anus, in March, 1928. They said the method causes relatively little postoperative pain, results in soft pliable scar tissue, causes little contracture, greatly decreases the amount of bleeding, and is easy to use. They used the knee-chest position, the proctoscope and local anesthesia for the removal of small lesions but for large malignant papillomas or ulcerating carcinomas they used a general anesthesia and they combined the treatment with radon applied directly to the base. This is followed with heavy cross-firing with radon seeds or deep roentgen therapy by using anal and sacrococcygeal portals. A suprapubic portal may be added if the growth is situated high in the rectum.

Electrocoagulation.—Strauss, Strauss, Crawford, and Strauss[21] reported that Kolischer introduced surgical diath-

ermy, in 1910, for the removal of inoperable malignant tumors. In 1913 they obtained excellent results in the treatment of three aged persons who had carcinoma of the rectum. In the past seven years they have used the procedure alone in practically all cases of cancer of the rectum which extends as high as the sigmoid colon. They employed an active electrode with a flat, round tip that was brought in contact with the tumor; the end of the electrode was bent at a right angle, and they employed a glass tube endoscope. The technic has been modified in that they now favor superficial coagulation which may be repeated two, three or four times at intervals of two or three weeks. They reported forty-two cases in which this method of treatment was used. Severe hemorrhage occurred in five cases at the end of the eighth to twelfth post-treatment days. In thirty-one cases the patients were in excellent condition. In twelve cases less than three years had elapsed since the treatment, in nine cases more than four years had elapsed, in seven cases more than five years had elapsed, in two cases more than six years had elapsed, and in one case more than seven years had elapsed. They said that in twenty-two cases in which colostomy was not performed, the results were excellent.

Surgical Diathermy Plus Radium Therapy.—One of us, Bowing,[3] has used surgical diathermy (bipolar current) to facilitate radium therapy in carcinoma of the rectum. The active electrode was a piece of no. 23 gauge music wire, 31 cm. long. The proctoscope was of the ordinary metal type. The active electrode was inserted for a depth of about 1 cm. into the substance of a medullary tumor. The region about the electrode was coagulated. The point of the electrode was withdrawn and another region was coagulated. Many regions were treated in this manner. An interval of six to seven days was permitted between coagulations. The tumor gradually became reduced in size until only the base remained and contact radium treatment was applied to this region. The initial and late responses to the combined coagulation and radium treatment were satisfactory. A similar technic is used when radium puncture is to be done. However, coagulation and

puncture are done with the same anesthetic. There is practically no bleeding and it is easy to determine the exact site of each radium needle. The same method is used for the placement of gold radon seeds. There is a possibility that superficial coagulation does reduce the surface infection in that all punctures are made through coagulated tissue. No troublesome local infection has occurred.

COMMENT

The brevity we have attempted to maintain throughout this presentation has been a truly severe taskmaster. We appreciate that valuable data have been curtailed or omitted. The treatment frontiers have as yet been only partially explored. Much remains to be accomplished before the patient, clinician, surgeon, radiologist and pathologist will be satisfied with their results in the treatment of cancer of the rectum. Finally, the most important single consideration probably would be that we have sufficient evidence to prove that cancer of the rectum may be prevented through the early recognition and treatment of rectal polyps and precancerous lesions.

SUMMARY

Valuable data have accumulated concerning malignant neoplastic diseases of the anus, rectum and sigmoid colon, and this information surely has advanced our knowledge of this insidious disease. As a natural sequence, much responsibility has been placed upon those concerned in the possible recovery of the patients. In a measure, the symptoms and diagnostic signs vary according to the region that is involved. Further, the age and general condition of the patient, the duration of the disease, and physical characteristics, furnish problems in diagnosis, treatment and prognosis. The management of the patients demands great skill, judgment, care and complete physiotherapy equipment. The selection of the patients suitable for a conservative or a radical therapeutic measure is best made by those who are experienced in this field of cancer

work. Electrosurgery or actual cauterization, and radium therapy and roentgen therapy are not competitive measures but are decidedly complementary. They can be employed singly or in many combinations. Full co-operation by all concerned is essential for good results The outlook, for the future, is very encouraging. This is especially true if the patients are seen early in the course of the disease and if the proper procedures are selected to meet the individual requirements of the patient seeking medical and surgical care.

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TREATMENT OF NONMALIGNANT CONDITIONS WITH RADIUM

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Each new therapeutic method has an interesting life cycle. After discovery, a natural enthusiasm causes nearly every possible disease to be subjected to the new treatment. Gradually the curve of usefulness declines with the disillusionment and discouragement attendant on applying the treatment to diseases not favorably influenced. Finally, if the method of treatment is sound, the curve rises again as the method is restricted to the diseases in which its value has been proved.

Treatment with radium is in this third phase. The lesions that respond to treatment have been recognized and treatment has been intensified with gratifying results.

Treatment of malignant lesions conscripts most of the available radium as well as the time and efforts of radiologists. However, with the increasing importation of radium into this country there has been a steady development of the treatment of various benign conditions. The radiologist has maintained his enthusiasm because of the interesting diversity of the lesions, many of which are common and some rare, and because either marked benefit or cure has been invariably attained with efficient treatment. At the Clinic, the percentage of patients treated with radium for benign conditions, compared with those treated for malignant processes has increased from 33 per cent in 1932 to 43 per cent in 1939.

Nonmalignant conditions that respond favorably to irradiation may be grouped as benign tumors and as acute or chronic inflammatory processes. Some of these lesions occur frequently, others are extremely rare.[3]

BENIGN TUMORS

Hemangioma.—Among benign tumors, *congenital nevi* or *birth marks* of infants form a large group. Treatment with

Fig. 73.—Cavernous hemangioma before treatment with radium (reproduced by the courtesy of Minnesota Medicine).

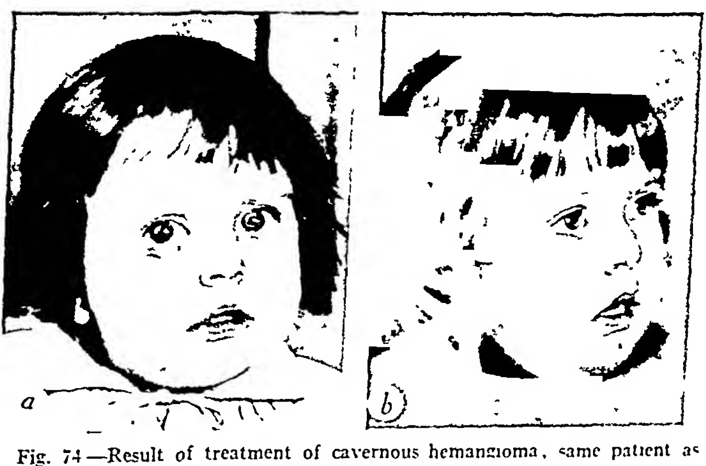

Fig. 74.—Result of treatment of cavernous hemangioma, same patient as shown in Fig. 73; *a*, eight months after institution of treatment, two treatments with radium had been given, *b*, sixteen months after institution of treatment. (Figure 74, *a*, is reproduced by the courtesy of Minnesota Medicine.)

radium yields the best results in cases of certain types of nevi.[8] The superficial or common strawberry type of dark red birth mark is amenable to treatment. *Cavernous hemangiomas,* deeper lesions spreading widely beneath the skin that have a dark red or a bluish, superficial discoloration, also respond fairly well to repeated treatments over a long period. Certain *capillary types* of hemangioma are resistant to radium therapy, as is the diffuse *port-wine stain.* These forms of nevi are sometimes treated more successfully with solid carbon dioxide, electrodesiccation or surgical excision. Occasionally, good results are obtained with radium in cases of port-wine stains, but only among infants.

In general, results in the treatment of hemangiomas are always better if the patient is young. I prefer to treat all of these patients when they are one year of age or younger. Many excellent results are obtained if treatment is commenced when the patient is only a few weeks or months of age (Figs. 73 and 74, *a* and *b*).

It is important that treatment be *conservative* and *cautious.* Parents always are informed that a year or two may be required in order to achieve a satisfactory result. Overtreatment must be avoided. Telangiectasis resulting from overtreatment is as unsightly as the original lesion. Treatment is repeated every three to four months until satisfactory regression of the tumor occurs. The tumors themselves extend downward and occupy more subcutaneous tissue than usually is realized. The parents are assured before treatment starts that perfect restoration of the parts cannot be expected; gradual shrinkage of the tumor under treatment is accompanied by less disfiguring scar tissue than is produced by other available forms of treatment.

Lymphangioma.—Lymphangiomas are not as sensitive to radiation as hemangiomas, but satisfactory regression is to be expected. Treatment is tedious and results are slow. Radium used at a distance is the best and safest method, although in some instances radium needles or seeds yield satisfactory results.

Cystic Hygroma.—One of the more rare benign tumors is cystic hygroma. This tumor which is congenital usually be-

Fig 75—Large cystic hygroma of the neck before treatment

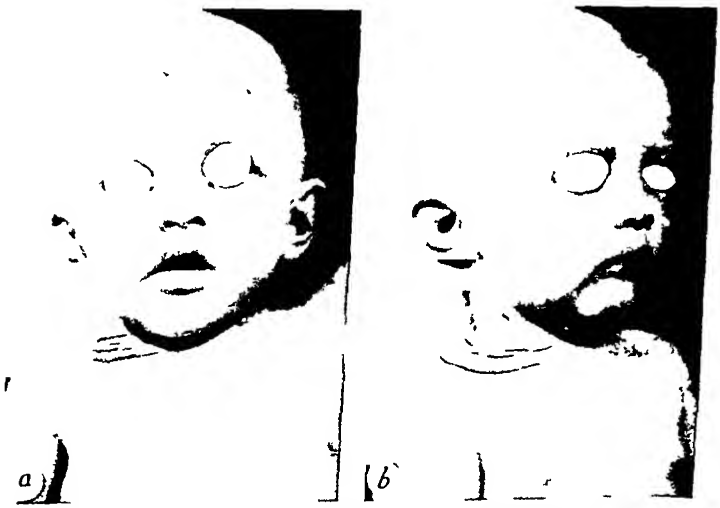

Fig 76—*a* and *b*, Eight months after institution of treatment with radium for cystic hygroma, same patient as shown in Fig 75

comes evident in the first four years of life It usually is lobulated, cystic and bluish, contains lymph, is lined with

endothelial cells and usually is situated in the lower half of the neck.[4] Lymph is obtained on aspiration of the tumor. This, together with the cystic appearance of the swelling distinguishes it from branchial cleft cyst, lipoma, aneurysm or infected lymph node. As the tumor increases in size, pressure may produce dyspnea and dysphagia.

Surgical extirpation of this rare tumor never has been satisfactory. If it is not removed completely, recurrence from one of the remaining lobules is common. Often, extension of the tumor into the mediastinum or axilla precludes complete excision. Radium therapy given cautiously over a year or two, with treatments three or four months apart, gradually causes shrinkage and finally disappearance of the growth (Figs. 75 and 76, *a* and *b*). Results are excellent unless infection occurs. This may supervene at any time before the tumor disappears and usually progresses to ulceration, drainage and death. Infection occurs as readily in cases in which treatment has not been given and treatment never has been known to increase the risk. The mechanism of the favorable effect of irradiation on these tumors is not known precisely; probably it consists of destruction of the endothelial cells of the cysts, which are believed to form the lymph.

Lymphedema of the Face.—Another rare condition which occurs among adults and one that is best treated with radium is lymphedema of the face. It is difficult to know whether to classify this as a benign tumor or an inflammatory condition. The disorder was reported as a clinical entity by New and Kirch in 1933; they studied sixty-seven cases treated at the Clinic in twenty-two years. The acute edema, which leaves permanent residual swelling, chiefly involves the lips, eyelids and cheeks. Good results are attained by injections of boiling water followed by treatment with radium; again, as in cases of cystic hygroma, treatment is given every three or four months for one to two years.

Fibromyoma of the Uterus and Menorrhagia.—Among the largest group of benign tumors treated with radium are fibromyomas of the uterus. These tumors are common, but only

when menorrhagia develops or when they increase in size and produce symptoms of pressure is treatment necessary. Before the development of irradiation a major surgical procedure was the only treatment available; myomectomy or hysterectomy was indicated. Now radium has become a safe and efficient substitute for some major operations for this condition. However, the patients that will be benefited must be selected carefully. There are important indications and contraindications in regard to this form of treatment.[2]

If the fibromyomas are causing definite symptoms, such as menorrhagia or pressure on neighboring organs, careful *pelvic examination* is necessary, performed preferably with the use of anesthesia in order to exclude adnexal disease or abnormalities. *Curettage* for diagnostic purposes is essential to be sure that carcinoma of the fundus is not causing the bleeding. Once the diagnosis of simple fibromyoma is established, intra-uterine treatment with radium generally is effectual. The treatment entails no risk beyond that of curettage.

Types of Fibromyomas Which Should Be Treated Surgically.—Submucous tumors tend to considerable sloughing after treatment; subperitoneal tumors may not be affected favorably because of their distance from the radium capsule in the uterine fundus. Tumors which enlarge rapidly or disclose marked softening should be excised surgically, as these changes may denote malignant degeneration. Firm tumors which contain large amounts of calcium as disclosed by the roentgenogram are resistant to radium therapy. Operation also is preferable when adnexal abnormality or disease is present so that the associated trouble can be removed.

Radium Treatment of Fibromyomas; Its Results.—The radium or radon in a small brass tube fastened with wire is inserted into the depth of the body of the uterus usually at the time of the diagnostic curettage. Fifty milligrams of radium element or a 50 mc. radon tube stays in place for about twenty-four hours and causes little or no discomfort to the patient; after removal of the radium, an additional stay of

twenty-four hours in the hospital is advisable to be sure that there are no disturbing after effects.

In carefully selected cases, results of treatment are gradual and all that could be desired. Cessation of menstrual flow and disappearance or diminution of the tumor occur gradually over many months. In instances in which a favorable effect is not achieved, an interval of six months should elapse before repetition of the treatment. Surveys of results in many large series of cases have revealed a perfect outcome in the majority of instances; certainly, repetition of treatment rarely is necessary.

One of the principal perplexities of gynecologists is the question of *size* of the tumor determining operation or irradiation. Some physicians consider that a myomatous uterus larger than the uterus after three and a half months of pregnancy contraindicates treatment with irradiation; others feel that a large tumor can be treated effectually. Of course, when the excessive size of the tumor produces serious pressure on neighboring structures, operation affords immediate relief as compared to the gradual relief afforded by slow shrinkage of the tumor from irradiation.

Menorrhagia of the Menopause.—Menorrhagia of the menopause without a demonstrable fibromyoma is treated most safely and efficiently by the intra-uterine application of radium. There is definite need to educate women in the fifth decade of life so that they will present themselves for treatment earlier in the course of the disease and not to expect a definite menorrhagia to correct itself because they are at the menopausal age. Too many women wait until excessive bleeding leaves them depleted and anemic, so that blood transfusions and supportive measures have to be instituted before menorrhagia can be combated. Among patients who have essential menorrhagia and whose general health is satisfactory, treatment with radium is practically specific. Kelly has termed radium the modern medical miracle in connection with this dsease. The treatment is safe, rapid and efficient. The radium is introduced into the uterus at the time of diagnostic curettage; curettage

is essential to exclude carcinoma of the uterine fundus. Thus, a minor surgical procedure is substituted for hysterectomy, which was necessary before the use of radium in medicine. Results in our experience have been extremely satisfactory in at least 95 per cent of cases; in 5 per cent or less, repetition of the treatment six months to a year later or subsequent hysterectomy may become necessary.

Menorrhagia in Girls and Young Women.—Treatment with radium in cases of menorrhagia among girls or young women is employed only as a last resort after failure of all possible medical or surgical treatment because even the small or moderate dose of radium employed has been known to produce permanent amenorrhea among some women. This unfortunate result seems to arise from differing degrees of sensitiveness of the ovaries to irradiation, which at present cannot be estimated beforehand. When all other methods fail, severe menorrhagia can be relieved by intra-uterine application of small doses of radium, although the risk of permanent amenorrhea must be explained to, and be appreciated by, the patient and her relatives.

Fibrous Plaques of the Penis (*Peyronie's Disease*).—Histologically, fibrous plaques of the penis are composed of elastic fibers and connective tissue and resemble keloids. Although the disease was described as long ago as 1743 by Peyronie, the etiology has never been determined satisfactorily. Peyronie's disease has been studied exhaustively. The indurated regions usually are situated on the dorsum of the penis; they involve the sheaths of the corpora cavernosa and septum and may appear as a nodule, a plaque or a cordlike thickening. The swelling is readily palpable. The urethra and corpus spongiosum are not affected. The disease produces deformity on erection which may or may not be painful, but sexual intercourse is rendered difficult or impossible. Although the disorder has no vital significance, it tends to produce much mental suffering and may lead to grave psychotic changes.

Treatment has been varied and in the main discouraging. Surgical excision, diathermy and administration of fibrolysin

or iodides have been tried with but little success. The use of roentgen rays has given some encouraging results. For many years, keloids had been found to respond well to radium. The first successful use of radium in cases of Peyronie's disease was reported by a German physician in 1911, who treated the condition with heavily filtered radium similar to treatment given for a keloid.

Although the incidence of Peyronie's disease is rare, 549 cases had been reported in the literature up to 1928; more cases are being recognized as interest in this condition increases. For several years about twelve to twenty patients a year have been treated with radium at the Clinic for this disease. The results of treatment with radium have been mildly encouraging and the cures have slightly more than equaled the cures achieved by all other methods of treatment combined.[5] The lesions are treated just as are keloids; heavily filtered rays of radium which pass through 2 mm. of lead, as well as the primary silver and brass filters, are used. Suberythema doses are employed. To be effective, the treatment must be repeated two or three times at intervals of three to four months. Experience has demonstrated that treatment is more effective when the diagnosis is made early in the course of the disease, just as keloids which are diagnosed early are more readily absorbed by irradiation. Cartilage and bone have formed in fibrous plaques of several years' duration and these tissues are resistant to irradiation. Treatment is simple and safe and requires only an overnight application of the element.

Verruca Vulgaris.—Verruca vulgaris, or the common wart, is a benign tumor which usually responds readily to treatment with radium. Beta irradiation is employed; for this a varnished, unfiltered plaque is used. One treatment is ordinarily sufficient. The few warts which prove resistant to irradiation should be excised surgically.

INFLAMMATORY LESIONS

Acute Inflammatory Lesions.—Among acute inflammatory lesions is the postoperative complication known as

postoperative acute parotitis.[1] In cases in which the patients are debilitated after a major surgical operation, most frequently after operation on the intestine, acute parotitis is attended by a grave prognosis. Death may occur in almost half of the cases unless treatment is prompt. In 1930, Rankin and Palmer compared a group of cases in which radium was used to one in which it was not; they found that the mortality rate was practically cut in half by the use of radium.[7] I cannot do better than to summarize the conclusions reached by Rankin and Palmer which were as follows: (1) radium, if applied immediately on recognition of the infection, tends to abort suppuration and decrease mortality; (2) if surgical incision becomes necessary, the prognosis is more grave; (3) the extent of the infection, for example, bilateral involvement, increases the mortality rate; (4) the more serious the operation preceding the infection, the higher is the mortality rate, as disclosed by studies of operations on the colon and (5) the mechanism of the beneficial action of radium is unknown, but one possible theory is that the resultant disintegration of the protective leukocytic barrier liberates protective antibodies or ferments.

For several years patients with this serious complication have been treated at the Clinic with encouraging results. Radium is carried to the bedside and applied as soon as the diagnosis is established. As a rule, the inflammatory process subsides satisfactorily about the second or third day after completion of treatment. The treatment is painless, without risk and is well tolerated.

Large, *acute abscesses* or *carbuncles* respond perfectly to treatment with radium. Radium can be carried to the bedside, thus avoiding the risk of transportation of the extremely ill patient. The important feature is the immediate application of the treatment at any time of the day or night that the acute infection is recognized.

Chronic Inflammatory Lesions.—Among chronic inflammatory processes, *tuberculous adenitis* has long been recognized as being sensitive to irradiation. Treatment should be

repeated at intervals of three or four months, often for years. Biopsy of a chronically enlarged lymph node establishes the diagnosis and treatment with radium gradually shrinks the involved nodes and causes deposition of scar tissue.

Actinomycosis of the cervical lymph nodes is a stubborn process and very resistant to treatment: treatment with radium or roentgen rays, however, has been successful in these cases. Repeated treatment over a long period is required.

SUMMARY AND CONCLUSIONS

In general, treatment with radium of all benign lesions, whether neoplastic or inflammatory, necessitates certain precautions. Most of these conditions are not fatal if not treated. By overtreatment, underfiltration of radium or lack of protection to adjoining tissues, a benign condition may be changed into a malignant one. Unskilled treatment may cause serious damage to the skin and underlying tissues, necessitating surgical repair. To the patient, treatment with radium often is considered just treatment with radium: he has heard of marvelous cures and expects the same, with no thought as to the experience or the equipment of the radiologist.

Although the patient will eventually learn that skill and experience are as important to a radiologist as to a surgeon, a saving factor is that of dosage in treating benign disease. Good results can be achieved in all the benign conditions mentioned, although some are serious conditions. However, in all these lesions only a percentage of the dose used in treatment of carcinoma need be employed. The dosage used is never a full erythema dose. This additional safeguard, plus the growing skill and experience of the radiologist makes the treatment of benign disease one of the most satisfying and fascinating fields in the domain of therapy.

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ROENTGENOLOGIC TREATMENT OF BENIGN, INCLUDING INFLAMMATORY, CONDITIONS

WALTER C. POPP

The use of roentgen therapy in the field of benign, and particularly inflammatory, lesions is ever widening. It is intended in this article to comment on the use of roentgen therapy in benign lesions considered amenable to this type of treatment, as well as recent conceptions in treating inflammatory conditions. Perhaps the most prominent advances in the treatment of nonmalignant condition in recent years have been in connection with inflammatory lesions; for this reason these will be mentioned first. The practical method of classifying types of inflammatory lesions for the purpose of discussion has been to consider the *acute* and *chronic* phases; hence, this arrangement will be followed.

Dosage used in treatment of inflammatory conditions and the majority of benign conditions is relatively small. At the Clinic, we have found that such dosages are equally beneficial and assist in the ultimate protection of the skin so that deleterious effects need not occur. Throughout this article it will be noted that, with the exception of only two conditions, those of fibroids and of artificial menopause, the dosages suggested are relatively small.

ACUTE INFLAMMATORY CONDITIONS

In general, acute inflammatory conditions are treated with relatively small doses of roentgen rays consistent with the type and location of the lesion. The resolution of acute inflammatory conditions usually is rapid; thus, a small amount of

treatment usually is sufficient. The *voltage* used in this type of treatment need not exceed 120 to 140 kv. The *filtration* necessary is determined by the depth as well as the location of the lesion.

Furuncle.—Experience at the Clinic has been that when a furuncle is treated early, that is, within twenty-four to forty-eight hours after its inception, the inflammation commonly undergoes involution without suppuration. The amount of necessary treatment depends on the size and relative acute condition of the lesion. If the lesion is of twenty-four to forty-eight hours' duration, the treatment need not exceed 50 to 75 r, with voltage and filtration dependent on the size and thickness of the affected region. When the lesion has been present more than seventy-two hours, a dose of 75 to 100 r may be used. When suppuration develops, it usually appears within forty-eight hours after the first treatment has been given. The treatment should be repeated every other day. As a rule, three sessions of treatment are sufficient. Of particular interest are furuncles of the *nasal orifice* and *external auditory canal.* Because of the difficulty of approach for local treatment, the use of roentgen rays is of great value. A furuncle in these situations responds to treatment as well as a furuncle in any other region. Occasionally, a furuncle on an extremity may be associated with *lymphangitis;* experience at the Clinic has been that the lymphangitis as well as the primary lesion should be treated. If the general condition of the patient is not altered by some serious complication, the same results are obtained as in cases in which lymphangitis was not present.

Carbuncle.—Roentgen therapy for carbuncles is usually the same as for furuncles, except that the treatment may have to be repeated oftener. Assuming that by the usual definition a carbuncle is a localized cutaneous infection with multiple openings, the treatment should include not only the lesion itself but also a fairly wide margin of the normal surrounding tissue. As a carbuncle usually is present somewhat longer than a furuncle, slightly larger dosages may be used. I have found that a dose of 75 to 100 r, repeated every other day until a total

of not more than four sessions of treatment has been given, is sufficient in the average case. After the second session of treatment, the lesion usually reveals some evidence of pointing, provided drainage was not present before treatment was instituted. When the carbuncle is pointing, drainage should be promoted by a small incision over the region of suppuration. Under ordinary circumstances, a carbuncle can be cured in this manner without extensive surgical interference.

If a carbuncle is a complication of diabetes, the same course of treatment is followed: if the diabetes is under control, the same final results may be obtained.

Simple Adenitis.—This condition usually is seen among children and usually is coexistent with an acute infection of the upper part of the respiratory tract. As a rule, the lymph nodes are tender and the patients often have fever. The involved lymph nodes are treated with a small dose in the range of 50 to 100 r. The treatment is repeated only if it seems necessary and commonly an average of only two treatments on alternate days is necessary. As a rule, the adenitis subsides completely.

Erysipelas.—The average case of erysipelas can be brought under control by means of roentgen therapy within twenty-four to seventy-two hours. The best results are obtained if the patient has fever. In most cases, the dose need not exceed 125 r of unfiltered roentgen rays at a voltage of approximately 80 kv. to the involved regions and, at the same time, to a fairly wide margin of normal surrounding tissue. Erysipelas in cases of aged patients responds to roentgen therapy, but in a less dramatic manner. If the cutaneous lesion discloses evidence of extension after the first treatment, such regions should be treated as they develop. It is not necessary to treat more than once in the majority of cases. When fever is present, the temperature usually falls to normal within twenty-four hours after treatment.

Sinusitis.—Because of conflicting ideas about the treatment of acute sinusitis, a series of such patients has been treated with roentgen rays recently and the results have been

evaluated in collaboration with a rhinologist. As this treatment of acute sinusitis is relatively new, it might be well to give the results obtained in this series.

Fifty-six patients were treated. In thirty-one cases severe involvement was present and in twenty-five moderately severe involvement. Because of reports in the literature that treatment given early in the course of the infection is more effective than when given late, both groups were arbitrarily divided into those in which symptoms had been present *for one to five days* before the beginning of treatment and those in which the symptoms had been present *more than five days.*

In the thirteen cases of severe sinusitis, in which pain and tenderness had been present from one to five days before roentgen therapy was instituted, were six cases in which pain and tenderness disappeared within six hours after the first treatment and one case in which pain and tenderness disappeared abruptly after the second treatment. In an additional case in which relatively large doses had been used, the symptoms increased for three days and then stopped abruptly; the nasal discharge and inflammatory swelling of the nasal mucosa subsided completely by the evening of the third day after treatment. In two other cases, the pain and tenderness continued until after the third treatment, when these symptoms suddenly disappeared. These results were classified as moderately good. In three cases roentgen therapy had no apparent effect.

Eighteen patients had had *severe* sinusitis for more than five days. The pain and tenderness of nine disappeared after the first treatment and these same symptoms and signs of two disappeared after the second treatment. These results were regarded as good. Pain and tenderness disappeared in one case after the third treatment; this was assumed to be a moderately good result. In six cases roentgen therapy did not have any apparent effect. In one of these cases trephination was required because of edema over the frontal region and high fever associated with leukocytosis, which suggested incipient osteomyelitis of the frontal bone. Another patient in this group had a complicating orbital abscess and an abscess of the

frontal lobe of the brain. This patient died three months later of the abscess. This was the only death in the series.

In eight of the cases of *moderately severe* sinusitis in which symptoms had been present for from one to five days, pain and tenderness disappeared after the first treatment and, in one, this response was delayed until after the second treatment. In this group, all cases responded to treatment. In sixteen cases of moderately severe sinusitis, pain and tenderness had been present more than five days. In eight of these cases, there was complete remission of pain and tenderness within six hours after the first roentgen treatment. In one of the cases in which the patient apparently obtained complete relief after the first treatment, the symptoms recurred two weeks later; removal of a diseased pharyngeal bursa and submucous resection of the nasal septum were required.

Only a moderately good result was obtained in six cases. One patient, who received an unusually heavy dose, had an increase in pain and tenderness for four days, but this was followed by an abrupt cessation of all symptoms of sinusitis, including pain, tenderness, discharge and evidence of congestion of the nasal mucosa. In the five other cases in which the result was only moderately good the pain and tenderness were relieved but the discharge into the nose seemed unusually prolonged. In two cases, roentgen therapy did not have any apparent effect.

Because of the experience gained in treating other acute inflammatory conditions, it was felt that acute sinusitis might be treated equally well with relatively small doses. Treatment was given only in cases of sinusitis in which symptoms and objective evidence of involvement were present. If a patient's condition was diagnosed as pansinusitis, all the sinuses were treated. Otherwise, only the involved sinus or sinuses were treated. In each case, the doses used were in accordance with the duration and severity of the infection.

When the patients had had symptoms for from one to five days, doses of 50 r were used. When symptoms had been present for more than five days, doses of 75 to 100 r were used.

In each case the treatment was repeated every other day and from one to three sessions of treatment were given: the number depended on the symptomatic response. The treatments were given with voltages generated at 130 kv. (constant potential) filtered through 6 mm. of aluminum; for children a filtration of 4 mm. of aluminum was used at a distance of 40 cm. In each case the fields were sufficiently large to cover adequately the sinus or sinuses involved as well as the regions of nasal mucosa contiguous to the natural ostia of the involved sinuses.

CHRONIC INFLAMMATORY CONDITIONS

In the treatment of chronic inflammatory conditions, relatively larger dosages are necessary than for acute inflammatory conditions. The voltage and the filtration are much the same, but the number of roentgens used is decidedly increased. For example, in an acute inflammatory condition not more than 100 r is indicated, whereas in chronic inflammatory conditions doses between 150 to 250 r may be used according to the voltage and filtration employed. The treatment should be repeated at much longer intervals and, hence, the time consumed in attempting to eliminate the pathologic condition is considerably greater.

Actinomycosis.—Actinomycosis about the head and neck usually is treated with roentgen rays in conjunction with surgical drainage and oral administration of potassium iodide. Provided the process has not extended to the point where intracranial involvement is a possibility, the average infection clears up in six months to a year. Treatments are given with the voltages and filters adapted on the basis of the depth of the lesion; a dosage of approximately 250 r is used. This treatment usually is repeated at intervals of three to four weeks until the lesion seems quiescent. As a rule, not more than five or six sessions of treatment are required. Roentgen therapy alone is not sufficient for the care of actinomycosis and surgical drainage and administration of iodides should not be omitted. During recent years the treatment of actinomycosis of the ab-

domen and thorax has improved considerably and now actinomycosis can be cured in some of these cases.

Blastomycosis.—Blastomycosis is treated much the same as actinomycosis; the dosages and intervals of treatment are approximately the same. It has been our experience at the Clinic that the results in cases of blastomycosis, except for the cutaneous type, have not been as satisfactory as in cases of actinomycosis.

Arthritis.—It is difficult to evaluate the results obtained by roentgen therapy in arthritis because the majority of patients were under a general medical regimen at the time treatment was given. Although considerable improvement often followed treatment, to attribute this exclusively to roentgen therapy might be misleading. However, as arthritis is primarily an infectious disease, the use of roentgen therapy is indicated in selected cases. The involved joints should be treated thoroughly through one or more fields; the number of fields depends on the size of the joint. Perceptible or substantial improvement often is not obtained until two or three courses of treatment have been given at intervals of three or four weeks.

Sinusitis.—Because of the larger doses required in the treatment of chronic sinusitis and because of the difficulty in estimating both the severity and end results in chronic sinusitis, this method of treatment has been used only in selected cases. Roentgen therapy is employed only in cases in which severe pain is present and operation is contraindicated. The treatment is given only to the point of relieving pain and congestion. The doses used vary between 150 and 200 r and are repeated only if specifically indicated. Our experience at the Clinic has been that chronic sinusitis has been cured with roentgen therapy alone in only a very few instances.

Tuberculous Adenitis.—Tuberculous adenitis, particularly among children, definitely is amenable to roentgen therapy. The lymph nodes are treated with dosages of approximately 200 to 250 r. The sessions of treatment are repeated at intervals of three or four weeks until maximal improvement

is obtained. The patient should then be kept under observation for at least a year in order to determine whether or not the lesions may again become active. Treatment of tuberculous adenitis of adults has revealed fair promise, but the response of the affected lymph nodes is even slower than that of children. It is possible to cure tuberculous adenitis of a child or adult, if the tuberculous process is not active in other parts of the body. When the lesions are active in other organs or tissues of the body, the possibility of obtaining a favorable result is lessened considerably.

Tuberculous Peritonitis.—The combination of roentgen therapy and complete rest is of considerable value in cases of tuberculous peritonitis. The amount of treatment is determined by the amount of activity and general condition of the patient. The dose should be approximately 150 r per field, but if the patient is very ill the treatment should be arranged so as not to tax the patient's tolerance. If the general condition of the patient is otherwise good, doses of 250 r can be given safely. The plan of treatment consists of marking off the anterior abdominal wall from the level of the xiphoid cartilage to the pubic region and from one midaxillary line to the other into four fields of equal size with the navel as the common center. The posterior aspect of the abdomen should be marked into four corresponding fields. Treatment is given through each field. In the average case, the course of treatment lasts eight to twelve days. If the doses used are as low as 150 r, treatment should be repeated in three weeks; if doses of 250 r are used, the treatment should be repeated at intervals of four weeks. The courses of treatment should be repeated until the patient is well or until maximal improvement is obtained. Three to five such courses of treatment may be necessary. It must be remembered that roentgen therapy should not be used to the exclusion of other supportive measures.

Scrofuloderma.—The use of roentgen therapy in cases of scrofuloderma has been helpful. Scrofuloderma cannot be treated with roentgen rays to the exclusion of other methods of treatment. The doses used are much the same as for tuber-

culous adenitis. Again, the voltage and filtration must be selected according to the location and size of the lesion.

Miscellaneous Lesions.—Many other inflammatory conditions are amenable to roentgen therapy, but they are too numerous to mention and my experience with different cases is too limited to permit absolute conclusions to be drawn. However, the important factor in the treatment of inflammatory conditions is the proper selection of dosage as well as the voltage and filtration. Voltages in excess of 140 kv. need never be used and a filtration of 4 mm. or 6 mm. of aluminum is sufficient. The target skin distance may vary to some extent but in our experience an average of 40 cm. is suitable, and allows adequate penetration with the voltage and filtration mentioned; higher voltages need not be used. As the majority of inflammatory lesions, except those of the thorax or abdomen, are on or relatively near the surface of the skin, higher voltages offer no additional value. In fact, even for most inflammatory processes of the thorax or abdomen, rays generated at 130 to 140 kv. are sufficient.

DERMATOLOGIC CONDITIONS

The use of roentgen rays in treatment of cutaneous lesions is of great value. However, there is no group of conditions in which roentgen rays are misused so much. In many cutaneous lesions, roentgen rays are of considerable help when used with other measures, but difficulties arise because roentgen rays are often used to the exclusion of other methods. The more common dermatologic lesions which are amenable to treatment will be commented on. As the majority of cutaneous lesions are treated with unfiltered rays, it is well to mention what is meant by the so-called *skin unit*. In general, the skin unit represents a threshold erythema dose with unfiltered roentgen rays, an approximate quantitative value of 300 r measured in air. In general, the term "skin unit" is probably a bad indication of dosage, but because of its general acceptance it is perhaps well to use the skin unit in this manner, provided its equivalent value is remembered.

Acne Vulgaris.—Of all diseases of the skin, acne vulgaris is perhaps the one for which treatment with roentgen rays is used most commonly. Each case must be selected carefully and certain contraindications should be mentioned. Patients, especially girls, who have acne and are between thirteen and approximately eighteen years of age should not receive roentgen therapy because acne at this time of life can commonly be cared for by other topical measures. It is well to wait until adolescence has passed sufficiently in order to determine whether or not the acne will persist. If the patient has been selected for roentgen treatment, other measures should not be excluded. Treatment by a dermatologist is important for the removal of comedones and the drainage of superficial pustules. If these measures are used, less irradiation is necessary and hence, the skin of the patient is exposed to less irritation by roentgen rays. It is well to remember that strong local applications should be avoided.

Many suggestions have been made as to the *dosage* which should be used, but I feel that no dose in excess of ½ skin unit (150 r), unfiltered, should be used at a single session of treatment and this should not be repeated in less than two weeks. At the Clinic it is felt that the so-called ¼ skin unit is not sufficient to offer much benefit, and that a dose in excess of ½ skin unit may lead to moderately excessive cutaneous reactions. If treatment has been begun, it is well to carry through a complete course and it should not be interrupted until the cutaneous lesions have been well controlled. For the average patient not more than 3 skin units or a total of 900 r should be given in any course of treatment. This dose must be curtailed further at times because of the effect of roentgen rays on an extremely sensitive skin, such as possessed by the fair haired, light skinned type of person. At times, it is necessary to use some filtration in the treatment of extensive acne, particularly when some complication in the form of pyoderma is present. In this event higher dosages are not necessary, but filtration seems to offer more satisfactory results.

Clavus.—Certain suggestions have been made that roent-

gen treatment of the ordinary corn is worth while. An occasional treatment may help to relieve the discomfort but unless the patient's footwear is changed, little permanent benefit results. Occasionally, the soft corn which usually is seen between the toes can be helped definitely with roentgen rays. We have found that by treating the lesion, with careful protection of the surrounding tissue and using a dose not in excess of 3/4 skin unit, a marked measure of relief can be obtained. It is occasionally necessary to repeat the treatment at monthly intervals until two or three treatments have been given; in our experience this has been sufficient. If the lesion is not amenable to this amount of treatment, further treatment should not be given.

Eczema.—The term "eczema" covers a variety of cutaneous lesions, particularly chronic infectious eczematoid dermatitis, atopic eczema and dermatitis venenata. Several other conditions could be included, but from the diagnostic standpoint they will not be considered. It is believed at the Clinic that roentgen therapy is an excellent palliative procedure to be used in conjunction with other methods of treatment, but in no sense of the word can it be regarded as a curative measure. A patient may be free of symptoms for a long time as the result of roentgen therapy, yet it is realized that some other factor must be responsible for the complete disappearance of the lesion. Unfiltered irradiation, when doses not in excess of 150 to 200 r at a single session of treatment are used, is adequate. Repetition of treatment may be necessary on several occasions. Perhaps in this condition more than in any other, a roentgenologist, because of the excellent palliative results, can be led into continuing treatment to the point of radiodermatitis. I think it is well to warn that as little treatment as possible be given under any circumstances.

Neurodermite.—This condition is commonly known by two other general terms, "lichen simplex chronica" and "lichen Widal." As a rule, unfiltered irradiation of approximately 3/4 to 1 skin unit for a single treatment is sufficient to alleviate the pruritus and reduce perceptibly the induration of the lesion.

Under ordinary circumstances, not more than two treatments given at monthly intervals are necessary.

Herpes Zoster.—Roentgen therapy in cases of herpes zoster is particularly advantageous in preventing postherpetic pain. If treatment is instituted early at the time the vesicles appear, the lesion can be eliminated rather rapidly and the postherpetic pain is diminished markedly. The nuclei of the nerves which are involved in the distribution of the herpes should be treated rather thoroughly. For example, if the origin of involvement is in the posterior root of the spinal nerves we feel that treatment should be given paravertebrally and moderate voltage technic and 4 or 6 mm. of aluminum filtration with an output of approximately 200 to 250 r per field should be used. In the event that postherpetic pain has developed and that the lesion has not been treated in its early stages, a fairly large number of patients can be relieved by means of this treatment. The treatment usually has to be repeated at monthly intervals until two or three such treatments have been given.

Hidradenitis Suppurativa.—This lesion involves the apocrine glands in the axillae, inguinal regions, perianal region and the mammary glands about the nipples. One or all of these regions may be involved. If the lesions are acute, relatively small doses of filtered radiation in the range of 75 to 125 r are used. If the lesion is chronic, doses of approximately 250 r are used and repeated at intervals of three to four weeks. Only in a small number of cases will roentgen rays alone produce so good a result that no other procedure is necessary. In the average case, it is necessary to use local applications in conjunction with roentgen rays, as well as administration of some form of chemotherapy. In certain instances, it is necessary after the active phase has subsided to treat the involved region surgically and then do a skin graft.

Hyperhidrosis.—This condition is common to the feet; roentgen rays are a helpful measure in controlling the amount of perspiration. An initial treatment of approximately 1 unit (300 r, unfiltered) should be used. There is usually an in-

crease in perspiration within the first week after the initial treatment. Treatment should be repeated in a month: if the results are not satisfactory, the third treatment should consist of filtered irradiation, in which approximately two-thirds of a threshhold erythema dose is used. If three such treatments do not produce satisfactory improvement, treatment should be discarded.

Trichosis.—This condition, which so commonly is considered suitable for roentgen therapy, should in our experience never be treated with roentgen rays. The dosage necessary to produce a permanent epilation is sufficient to produce cutaneous damage and ultimately results in permanent changes.

Keloid.—Keloidal formation, either postoperatively or as the result of burns, is usually amenable to treatment with roentgen rays. Approximately $\frac{3}{4}$ skin unit (225 r) should be given and this dose should be repeated monthly until three treatments have been given. A keloid which has been diagnosed early in its development will respond to this amount of treatment and little residue will remain. If the lesion has been present more than a year or two, additional treatment to alter the keloidal formation and occasionally some filtered irradiation is necessary. Under ordinary circumstances, it would take approximately six months for a keloid to subside: after the third treatment has been given, treatment should be discontinued for two or three months in order to determine the amount of improvement before further treatment is considered.

Mycosis Fungoides.—As this condition is a manifestation of lymphoblastoma, the treatment selected depends on the amount of involvement. The cutaneous lesions should be treated with unfiltered or filtered irradiation, depending entirely on the size and depth of the lesion. In no instance should more than three-fourths of a threshhold erythema dose be used. If adenopathy is present, as is expected in a case of true Hodgkin's disease, more extensive treatment should be used in order to cover the active gland-bearing regions. After the lesions have subsided and only pigmentation remains, treatment should be interrupted and reconsidered only on appear-

ance of new lesions. In the treatment of this condition, it is advisable to study the erythrocytes and leukocytes in the blood. An occasional differential blood count should be made in order to determine the type of cells present. It is possible, with careful treatment, to keep a patient who has mycosis fungoides in relatively good general health for many years.

Warts.—Warts, either the verruca plantaris or verruca vulgaris, receive the same treatment. Approximately 1500 to 2000 r of unfiltered irradiation carefully confined to the lesion is adequate for the average lesion. If the lesion does not respond to one treatment, treatment with approximately the same dosage can be repeated after four to six weeks. With this method approximately 60 to 70 per cent of the lesions are curable. The greatest difficulty which may arise in the treatment of warts is that the roentgenologist may not protect the surrounding tissues adequately. When this occurs, considerable irritation may result in the tissues surrounding the lesion and hence, considerable difficulty may be experienced by the patient. Dosages of more than 2000 r are suggested and have been used by some, but in my experience this amount of irradiation is not necessary.

Pruritus of the Anus and Vulva.—It is my feeling that irradiation should be used for pruritus about the anus and the vulva only in selected cases. If the pruritus is extremely severe, it can be used as a palliative procedure and not more than approximately ¾ skin unit of unfiltered radiation should be used. Because of the sensitivity of the mucous membrane about the rectum and vagina, much difficulty can arise as the result of the use of roentgen rays. We have found that it is especially important to be sure of the target skin distance because of the irregularity of the surrounding anatomic structures. Treatment of this type may be repeated at a specified interval, but treatment should be discarded if one treatment does not give the desired result.

Psoriasis.—This rather common condition responds to treatment with roentgen rays, but it is at best only palliative. Since the majority of patients who have psoriasis do not have

symptoms, except for the cosmetic appearance, roentgen rays should not be used. I say this because the condition undoubtedly will recur and irradiation can be used to the point of producing actinodermatitis and occasionally will result in development of an epithelioma. It has been our custom never to treat psoriasis with roentgen rays. However, a not uncommon complication in psoriasis is involvement of the fingernails and toenails associated with arthritis of the distal phalangeal joints. The use of roentgen rays in this complication is beneficial in both reducing the involvement of the nails and giving definite symptomatic relief from involvement of the joints. We have used approximately two-thirds of a threshold erythema dose with moderate voltage technic, filtered through 4 or 6 mm. of almuminum. The treatments are repeated each month until two or three courses of treatment have been given. Because of the relatively slow growth of the nails, approximately three months are necessary after the last treatment has been given in order to determine the results of treatment.

MISCELLANEOUS CONDITIONS

Fibroids.—The primary purpose of treatment of fibroids is to produce menopause, because it is well known that after the natural menopause occurs, fibroids tend to diminish in size. The selection of cases for this type of treatment must be made carefully because of the possibility that a malignant process might be present. Treatment is usually given through three fields. The fields measure approximately 15 by 15 cm., over the right and left lower quadrants of the abdomen anteriorly and over the sacral region posteriorly. The object of this plan of treatment is to irradiate adequately both ovaries and the uterus. The voltage used is between 180 and 200 kv. with a filtration of 0.75 mm. of copper and 1 mm. of aluminum; each field is given a suberythema dose of approximately 550 r. One treatment usually suffices to terminate menstruation permanently. Once this has occurred the fibroids gradually diminish in size, but maximal regression may require six to twelve months.

Asthma.—Approximately a sixth of all patients seen at the Clinic who have asthma are treated with roentgen rays. Of this group, at least 50 per cent obtain some measure of relief and approximately 30 per cent are relieved markedly. This treatment is not a curative measure, but like all other measures for asthma is a palliative procedure. I have used treatment in two different ways, but the one to be suggested seems to give the best results. One field of treatment to the mediastinum anteriorly and one corresponding field to the mediastinum posteriorly are used. The fields are approximately 10 by 15 cm.; the dosage is about 250 r to each field. The treatments are given with a moderate voltage technic with filtration through 6 mm. of aluminum. Treatment is not repeated unless it is definitely indicated and then not until at least a month has elapsed.

Menopause.—Indications for the necessity of creating an artificial menopause are apparent to any clinician. The treatment is identical with that suggested for the treatment of fibroids. After the treatment has been given, it is not uncommon for one or two periods of menstrual flow to follow at the normal interval, but this should cause little concern as the periods will undoubtedly cease thereafter.

Ovarian Dysfunction.—This term covers a variety of ovarian conditions. The most common, however, are amenorrhea, dysmenorrhea and sterility. It is necessary to select cases carefully for this type of treatment and decide whether the condition is attributable entirely to the ovaries or to both the ovaries and pituitary gland. Patients are treated according to the degree of involvement. Treatment is given to each ovary by the anterior approach and to the pituitary gland through bitemporal fields. A high-voltage technic of approximately 200 kv. ordinarily is used and a dose is not in excess of 100 r per field. It usually takes two or three months to determine the benefit derived from the treatment: treatment is not repeated unless it is specifically indicated.

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THE ROENTGEN RAY TREATMENT OF MALIGNANT TUMORS

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The dozens of annual visitors to the Curie Hospital in Rochester, Minnesota, may be classified in one of the following groups: (1) the physician who wants to see some "x-ray work" on his way to the depot at the end of his tour, (2) the roentgen ray specialist, who comes in to exchange ideas, (3) the nonroentgenologic specialist, usually a surgeon, who wishes to gain some knowledge of newer technics in roentgenology as it affects surgical practice and (4) the progressive general practitioner who is sincerely looking for information. It is for physicians in this latter group that this paper has been prepared, for it is believed that much valuable information which, unfortunately, it is almost impossible for them to obtain otherwise, can be supplied in this manner.

If he is a physician who has been out of medical school fifteen years or more the average physician heard practically nothing about roentgen ray therapy when he was a student. On the other hand, if he is a more recent graduate, it is probable that in medical college he was forced to listen to some indifferently presented, technical lectures given by a professor who usually was a diagnostic roentgenologist, and during his internship, his interest in roentgenology was confined as a whole to review of roentgenograms made of patients on his service, so that he formed the opinion that the "x-ray picture" is the whole of roentgenology. During the time this physician has been in practice, it is likely that he has been too busy or too tired or too indifferent to read and study highly technical and highly specialized books and papers on roentgen ray therapy, even though they may be available to him.

Possibly, at the meetings of such a physician's state medical association, he has heard only about the treatment of some specific disease, or it may be, in some instances, that the paper that most appealed to him was scheduled for delivery at 8:30 in the morning or at 4:30 in the afternoon, hours at which anyone's receptivity, so to speak, is naturally very bad. In such circumstances, the probability is that the physician would not hear the paper read, but would wait to examine it when it appeared in print. Or, perhaps, he might intend to ask the roentgenologist in the hospital with which he is associated for "the dope on the subject." Unfortunately, both he and the roentgenologist no doubt are busy men, so that the question is soon forgotten.

If, on the other hand, the physician does attend the presentation of the paper in which he is interested, he may derive little benefit from it, because the speaker speaks too fast, too indistinctly, too technically or too long. The net result is that the physician learns little about roentgen therapy.

The situation is different when the subject of keeping informed about advances in general medicine is concerned. To begin with, the general practitioner knows some of the vocabulary of the clinician; his interest and attention lie in medical fields, and detail men of various pharmaceutical houses have informed him about such things as the latest organic compounds and the vitamins and extracts of hormones which he may never use in his practice. But nobody has kept him conversant with roentgen therapy.

This paper was written in an attempt partially, at least, to correct such a deficiency. In a field so rapidly expanding as the field of roentgen therapy, much in the matters of opinion and advice is controversial and unstable. Therefore, the views expressed herein are necessarily personal ones and are subject to challenge and contradiction by roentgenologic specialists. Nevertheless, an attempt will be made to answer the oft-repeated question of the general practitioner of medicine: "What may roentgen rays be used for in my practice?"

PRIME ESSENTIAL FACTORS IN ROENTGEN THERAPY

I believe that almost the most important single factor in roentgen therapy is the application of the knowledge of the specific sensitiveness of normal cells and of the tumors derived from them. Of perhaps equal importance is a thorough familiarity on the part of the roentgenologist with the pathologic anatomy of tumors in general and of the anatomic aspects of the lymphatic system through which elements of such tumors are disseminated. In third place I should list a knowledge of radiophysics. Since roentgen therapy is not a technic for engineers or for physicists to follow, but is in all essentials a discipline for physicians to embrace, I am of the opinion that the relationship of physics to roentgenology is comparable to the relationship of pharmacology to medicine, or that of anatomy to surgery. Therefore, no one essential factor can be emphasized to the exclusion of the others.

TYPES OF ROENTGEN RAYS NOW EMPLOYED

In roentgen ray therapy four types of rays are in general use: (1) *low-voltage* roentgen rays, generated in intensities up to 100 kilovolts (100,000 volts), (2) moderate or *medium-voltage* roentgen rays, generated in intensities up to about 150 kilovolts, (3) *high-voltage* roentgen rays, generated in intensities up to about 220 kilovolts, and (4) *supervoltage* roentgen rays, generated in intensities from 400 to 1000 kilovolts and more.

Because of the highly developed science of atomic physics, both the quality and the quantity of a given beam of roentgen rays can be measured with precision. Developments in both physical and electrical technic enable the roentgenologist to have at his disposal safe and reliable apparatus for the development and administration of whatever dose of roentgen rays the clinical indications may demand.

SPECIFIC SENSITIVENESS OF CELLS TO IRRADIATION

As a result of the gradual accumulation of controlled experimental evidence, the biologic basis of roentgen therapy is

firmly established. One of the most useful and important laws established on this experimental background is the so-called *law of specific sensitiveness.* This may be briefly explained: each kind of cell of which the normal human body is composed has a sensitiveness to radiant energy which is a peculiar and specific property of that cell, and which is different from the sensitiveness of other kinds of cells. This law is a corollary of the basic so-called law of Bergonie and Tribondeau: "the sensitivity of cells to radiation varies directly with the reproductive capacity of the cells and inversely with their degree of differentiation." These laws explain the well-known fact that some cells react to low doses of roentgen rays, and that some cells are destroyed by doses of roentgen rays which only injure or which may not affect other cells.

On the basis of their decreasing sensitiveness to roentgen rays, *normal cells* may be classified as follows:

1. Lymphoid cells
2. Polymorphonuclear cells and eosinophils
3. Epithelial cells
   - A. The epithelium of the salivary glands
   - B. The epithelium of the testis and ovary
   - C. The basal cells of
     - a. The skin
     - b. The mucous membranes
     - c. The stomach
     - d. The small intestine
     - e. The lungs
     - f. The liver and the bile ducts
     - g. The kidneys
4. Endothelial cells of the blood vessels, pleura, peritoneum
5. Connective tissue cells
6. Muscle tissue cells
7. Osseous tissue cells
8. Adipose tissue cells
9. Nerve tissue cells

Two reservations must be kept in mind concerning the foregoing classification. First, any kind of tissue, no matter what its inherent sensitiveness, can be injured by a dose of roentgen rays sufficiently high: second. the radiosensitiveness of tissues as previously classified is subject to modification in certain nonessential details.

The so-called law of specific radiosensitiveness of cells is of the greatest importance in the roentgen ray treatment of tumors because tumors as a whole resemble in their range of sensitiveness the normal tissues from which they are derived. Therefore, the specific radiosensitiveness of a tumor furnishes fundamental indications for both treatment and prognosis, and explains why some tumors are incurable by roentgen therapy.

BIOLOGIC, HISTOLOGIC AND CYTOLOGIC EFFECTS OF ROENTGEN IRRADIATION

Since the inception of roentgen therapy it has been known that all doses of roentgen rays produce an *injury*, and that the magnitude of the injury dealt by such rays depends on the magnitude of the dose absorbed. True stimulation of normal and pathologic tissues by small doses of roentgen rays incontrovertibly has been shown to be nonexistent. Even though the essential mechanism of the effects of absorbed roentgen rays on the cell is well understood, the basic underlying reactions which occur by means of which the growth of cells is inhibited or destroyed are still unknown. However, for purposes of discussion, the main biologic effects of such irradiation may be stated to be *direct destruction of the nucleus* of the individual cell, and to some extent, exertion of an *indirect effect on the blood vessels* which supply the tissue affected. These twin effects follow in the course of other inflammatory reactions and end with the formation of scar tissue. The reactions will, of course, vary according to the sensitivity of the tissue irradiated and also according to the dose of roentgen rays absorbed by the tissue.

In this regard, it may be pointed out that much evidence exists to show that it is possible to *overdose*, so to speak, with roentgen rays, and thereby to produce secondary and often deleterious inflammatory reactions which nullify the primary (curative) effect produced in the tissues irradiated. The role of the factors which combine to produce this effect is largely not understood. Yet it has been known for many years that debilitated or cachectic patients do not tolerate roentgen ray

treatment well, and that their powers of response are minimal, probably because of depletion of their tissues' power of recuperation or regeneration. When he is planning a dose of roentgen rays for any lesion in a patient, the physician should keep in mind the ancient phrase, *primo nil nocere*.

Certain Minor Transient Effects of Roentgen Therapy.—It has been stated herein that all doses of roentgen rays absorbed by the body produce an injury which is dependent on the magnitude of the dose of roentgen rays absorbed. Usually, these injuries are of little consequence, are temporary and are self-limiting, and, if the likelihood of their occurrence is remembered, they can be minimized or avoided altogether. Certain parts of the body do not tolerate roentgen rays as well as do other parts. For example, the *salivary glands* are extremely radiosensitive. After exposing these glands to a direct dose of a half erythema or more, especially when the rays are penetrating, there occurs within a few hours a swelling of the glands, which may be confused with mumps by the inexperienced physician or by the patient. In the average case, however, the reaction subsides in a few hours and no sequelae are noted, except perhaps a temporary dryness of the patient's mouth. Also, the *upper half of the abdomen* does not tolerate irradiation as well as does the pelvis or the thorax. The reason, of course, is the greater sensitiveness of the intestines in comparison to the sensitiveness of the pelvic or thoracic organs.

After administration of moderate doses of roentgen rays to any part of the body there commonly occurs, within a few hours, the *x-ray reaction*. The severity of this reaction depends on the part of the body irradiated and on the intensity of the dose applied. The reaction may be only a sensation of lassitude for a short time. This is the mildest type of reaction, and, since it is inevitable that some degree of reaction will occur, is the degree of reaction striven for as the ideal by the roentgenologist. Often, however, this particular symptom is accompanied by headache, loss of appetite, prostration of some degree, nausea and often vomiting. Little can be done to relieve the reaction, which in the average case lasts only a

few hours. General medical treatment for a disturbed stomach usually is all that is necessary. However, in severe instances of this reaction, it may be necessary to administer a sedative agent. Many expedients have been used to prevent this reaction. Almost the only measures that have been found to be effective are thorough evacuation of the intestinal and urinary tracts before roentgen ray treatment, and reduction of the dose administered at one session. Severe reactions have been treated by many measures, such as the administration of sugar, of vitamin B, liver extract, nicotinic acid, or suppositories containing pentobarbital sodium.

Since roentgen ray *erythema* has a benign course, little attention to the skin of the patient is necessary in the average case. If drugs which increase the sensitiveness of the skin have been employed, the dose of roentgen rays should be reduced. If, for reasons of clinical expediency, a large dose must be administered (especially to a skin which has great sensitiveness), the use of some bland lotion such as Dodd's lotion may be recommended. The patient should be urged to avoid irritation of the skin by the application of heat, exposure to sunlight and by direct trauma.

THE APPLICATION OF ROENTGEN RAYS IN THE TREATMENT OF MALIGNANT TUMORS

Rationale of the Divided Dose.—If the dose of roentgen rays has been maintained within reasonable limits, repetition of treatment at suitable intervals (depending on the quality and quantity of the dose first administered) presents no risk. There is evidence to support the contention of some roentgenologists that all treatment should be administered with high-voltage roentgen rays because such treatment spares the skin, especially if the rays are heavily filtered. But it must be remembered that sparing the skin should not be emphasized at the cost of neglect of the effect in the subcutaneous tissues. Furthermore, since it is well known that both erythema and "reactions" can be produced by treatment with radium bombs and packs which emanate gamma rays, it seems unlikely that

treatment well, and that their powers of response are minimal, probably because of depletion of their tissues' power of recuperation or regeneration. When he is planning a dose of roentgen rays for any lesion in a patient, the physician should keep in mind the ancient phrase, *primo nil nocere.*

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there is a range of wavelengths of supervoltage roentgen rays which, in and by itself, confers immunity on the skin or other tissue.

Because of the inescapable fact that all doses of roentgen rays produce a certain degree of injury, the object of clinical roentgen therapy is to inflict maximal damage to the tumor with as little effect on normal tissues as possible, after due consideration of the biologic and clinical factors which enter into production of the desirable effect, with control of these factors as far as is possible.

It is obvious that the simplest way to minimize the effect of a dose of any medicament (and roentgen rays when clinically applied should be regarded in this light) is to divide the dose. This expedient, division of the dose, is as old as roentgen therapy. Division of the dose may be achieved in one of several ways.

"Hit-and-miss" Treatment.—"Hit-and-miss" treatment is administered to the point of an effect, usually to the point of injury, to the skin. This sort of treatment must be categorically condemned.

Treatment "Every So Often."—Division of the dose also may take the form of treatment administered "every so often." Under such a circumstance an effect may be obtained by administering a single dose, which is repeated at the option of the one who administers the treatment. This sort of treatment commonly leads to unsatisfactory results and, if it is not accurately controlled, is a common cause of roentgenologic injuries.

Simple Fractioned Dose.—A third form of division of dose is simple fraction. By this technic a prescribed quantitative dose is administered in halves or quarters or even smaller fractions, for reasons of clinical expediency, usually to minimize the "reaction" of the patient, who, generally, is not in good physical condition.

"Saturation" Treatment.—A fourth method of division of the dose is administration of the total dose by the "saturation method" or some modification of it.

Protracted-fractional Treatment.—A fifth method is divi-

sion of the dose according to the protracted-fractional technic. In the employment of this technic many times the number of roentgens which would produce an erythema dose if administered at one session can be applied to suitable tumors by suitable control of the physical factors of the dose and the time and spatial relationships of these factors.

It should be stated in passing that the protracted-fractional method of treatment is at present the most favored of all types, and treatment by other methods is regarded by some roentgenologists as decidedly inferior. In fairness, it should be stated that the method in question is of undoubted value in therapy for certain tumors, but that the advisability of general application of the protracted-fractional treatment to all tumors, regardless of their structure and situation, still is unsettled. Therefore, the exact status of the protracted-fractional method cannot be stated with finality, even though it offers much promise in the treatment of certain intra-oral and other lesions. At any rate, the method certainly is not a "cure-all," and it should be used by none but expert roentgen therapists if its true value is to be established.

The Anatomic Arrangement of Treatment.—At this point it might be advisable to mention the fact that visitors to the Curie Hospital in Rochester commonly ask, "How much do you give such and such a lesion?" but very rarely, "How do you arrange the treatment of such and such a lesion?" My conception, and this conception is based on long observation, is that the quantity of roentgen rays administered is less important than the anatomic arrangement of the treatment. Too much care cannot be taken in "setting up" the patient, so that he may comfortably endure the often tedious administration of the dose. It is important, also, to check and supervise the laying out of the fields of treatment with reference to the lesion and the direction of the roentgen ray beams through it. The surgeon would not attempt an operation on a gallbladder without adequate surgical training and adequate equipment. Nor would the surgeon follow the directions for the operation so implicitly as they might be given in a textbook. Unfortu-

nately, however, roentgen ray treatment is often administered by prescription, sometimes by those whose main and only qualification for the exacting work is possession of an *x*-ray machine. Too many physical and biologic variables are operative in therapeutic roentgenology to permit the substitution of mechanical equipment for mental equipment.

The Factor of Massive Doses.—Recent publicity has placed in the minds of many people and in the minds of physicians in general the conception that *power* and *equipment* in themselves assure excellence of treatment. It is thought that the more powerful the *x*-ray machine, the better will be the results of treatment. Although it is true, in general, that the main effect of roentgen rays on a tumor is a direct killing effect proportional to the dose of roentgen rays absorbed by the tumor, which absorption in turn is proportional to the magnitude of the physical components by means of which it is produced, there are nevertheless clinical and biologic roentgenologic effects which are inexplicable on the basis of the application of the curves of roentgen ray penetration. Many roentgenologists have insisted that both normal and pathologic tissues enter into the complex usually called "the clinical effect." On the basis of purely theoretic considerations, it would be ideal to increase the penetration of roentgen rays to the highest possible point. But in doing so, the factor must be considered of possible damage to normal surrounding tissues on which, unfortunately, hard roentgen rays confer no immunity but do, it is true, approach fulfillment of the ideal of highest depth dosage.

Those experienced in roentgenology have seen the fallacy of what might be called "the power drive against cancer" manifested too often to agree with the contention that the equipment with which roentgenologic treatment is administered is of fundamental importance, for the best of equipment in itself does not confer expertness on its user. The *method* by which a dose of roentgen rays is administered to a patient is of greater importance than the physical components of the dose. In other words, the *x*-ray machine is at most only the tool of

the physician who operates it. Clinical judgment and experience never can be replaced in roentgen therapy by the short course, or by the administration of treatment by prescriptions from textbooks. And as a matter of fact, to judge by my own experience, based on results of treatment which I have seen, the powers of the *x*-ray machine in some cases have been far beyond the capabilities of whoever used it.

The Erythema Dose of Roentgen Rays.—In the application of roentgen rays to all tissues of the body, clinical dosimetry is based on the erythema dose. The erythema dose serves several important functions, for not only is it an indication of the biologic effect by observation of which other effects can be compared, but also, it serves as a limit to which the skin can be "loaded," so to speak, and by evaluation of it in physical terms, a unit for all dosimetry is obtained. Even though it has been shown that the erythema dose is not accurately definable, it still may be said to possess a sufficient degree of precision to be used in practical clinical roentgenology. Erythema as pertaining to roentgen therapy may be defined as "a faint redness of the skin appearing one or two weeks after roentgen ray treatment, lasting about a month and fading to a tanning, leaving no visible cutaneous changes other than the pigmentation."

It has been shown that the erythema dose depends on many factors of biologic importance, among them the *quantitative dose* administered in a single treatment, and to a lesser extent, the quality (*wavelength*) of the roentgen ray beam. Like all biologic reactions, the reaction of the skin to constant doses of roentgen rays varies within certain limits, so that exact evaluation of this reaction in terms of physical constants is impossible. Some types of skin are more sensitive than others, such as, for example, the thin, velvety skin of blond persons, and parts of the body, such as the perineum and axilla. Other parts are somewhat more resistant, such as the skin of the face (except the eyelids). Even though the skin of some persons is more sensitive than the skins of others, it is universally agreed that true *idiosyncrasy* for roentgen rays does not exist. Even

though exact evaluation of the erythema dose in terms of precise physical constants is impossible, the fact should be kept in mind that it is possible, nevertheless, to arrive at an approximate evaluation of it in physical constants in relation to the different types of roentgen rays now in common use. Such an evaluation is contained in Table 1.

TABLE 1

ERYTHEMA DOSE OF ROENTGEN RAYS IN TERMS OF ROENTGENS*

Roentgen Rays, Intensity in Kilovolts	Dose at One Session, in Roentgens
Up to 100	300 to 400
100 to 160	550 to 600
160 to 220	600 to 700
220 to 400	900 to 1000
More than 600	1000 to 1200

* See text for definition of "roentgen."

It might be advisable at this point to define the "roentgen," which is, as has been implied, the internationally accepted constant by means of which the quantity of roentgen rays is measured. A "roentgen" may be said to be: "The quantity of *x* or gamma radiation such as that which the associated corpuscular emission per 0.001293 gram of air produces in air ions carrying 1 e.s.u. of quantity of electricity of either sign."

It has been stated elsewhere that "the living world knows no constants." This aphorism should be kept in the physician's mind in the application of physical methods of precision to evaluation of effects in the complex and variable biologic constituency of the human body, for the measurement of a variable cannot but lead to inconstant values.

Roentgen Rays Employed According to Types of Tumors.—As I have already mentioned (in the section, "Types of roentgen rays now employed"), generally there are four types of roentgen rays which are used for treatment. The application of these roentgen rays in the treatment of malignant tumors can be summarized somewhat as follows:

Low-voltage Roentgen Rays.—Low-voltage roentgen rays are used in the treatment of superficial lesions or tumors, when

production of a direct intense effect is possible, because of lack of intervening tissue between the surface of the skin and the tumor. Rodent ulcer is a lesion commonly treated by these roentgen rays.

Moderate-voltage Roentgen Rays.—Roentgen rays of moderate voltage can be employed when the tumor is not deeply seated (and in this particular circumstance depth is to be regarded as a relative term) or when the tumor is known to have a high degree of radiosensitiveness. In the section with which I am associated at the Clinic such roentgen rays have their greatest application in the treatment of the majority of patients who have lymphoblastoma, and in the treatment of those who have intra-abdominal and intrathoracic metastasis of radiosensitive tumors, and in the postoperative treatment of patients who have carcinoma of the breast. The clinical efficacy of treatment with rays generated at moderate voltage in properly selected cases cannot be explained entirely on the basis of physical considerations of depth of dose.

High-Voltage Roentgen Rays.—High-voltage roentgen rays are those commonly used in so-called deep roentgen therapy. This term is a misnomer, since all roentgen therapy is more or less "deep." In my experience irradiation of this quality is best reserved for deep-seated tumors; for example, those situated in the pelvis, or those of known resistance to roentgen rays, such as tumors of the brain, tumors of the kidney and metastatic invasion of lymph nodes in the neck. Unlike many other roentgenologists, I feel that the use of penetrating roentgen rays, especially in high dosages, definitely should be carried out only after strict indications. To me, at least, it seems that the routine use of roentgen rays of a voltage of 200 kv. in the postoperative treatment of patients who have lesions of the breast is unnecessary, for injurious effects of absorption in the lung are not infrequently encountered after such treatment; also, I feel that at best these reactions produced in pulmonary tissues have nothing whatever to do with the response of the lesion theoretically present in the thoracic wall. Also, the indiscriminate use of protracted-fractional roentgen ray

treatment at a voltage of 200 kv., with high filtration of the sensitive lesions of lymphoblastoma or seminoma, does not seem to me to be wise.

Supervoltage Roentgen Rays.—Supervoltage roentgen therapy still is partly in the experimental stage. When a deep-seated resistant pelvic, thoracic, or abdominal tumor is thought to require the largest doses consistent with the safety of overlying tissues, such irradiation may be indicated. Aside from its theoretic advantage of higher depth dose and perhaps better toleration by both the skin and the patient of such treatment, the clinical status of supervoltage roentgen therapy is yet to be established.

THE FOUR ROENTGENOLOGIC SUBDIVISIONS OF TUMORS

Without further elaboration, it may be said that the radiosensitiveness of tumors parallels that of their normal cellular prototypes. This conception permits rapid subdivision of all tumors into *four classes:* (1) those which theoretically and under ideal conditions can be cured by roentgen rays because they are radiosensitive, (2) those in the treatment of which roentgen rays should be combined with other methods, (3) those which cannot be cured by roentgen rays because of their resistance to these rays and (4) those in which treatment by roentgen rays is still experimental.

This subdivision or classification of tumors is subject to further modification, depending on *the stage of the tumor* at the time the patient visits the physician for treatment, and *the efficacy of other nonroentgenologic or radiologic methods* of treatment. It may happen that the surgical results of treatment of a given lesion are so successful that roentgen ray treatment of it may be accorded secondary consideration, no matter what the theoretic reactivity of the particular tumor may be.

It is a long established general principle that the best treatment for malignant tumors in general is *surgical operation.* That principle necessarily limits the field of application of roentgen ray therapy largely to inoperable tumors, or to tumors

the surgical ablation of which would be accompanied by excessive risk to the patients. For this reason, decision as to allocation of tumor-afflicted patients for primarily roentgenologic or primarily surgical treatment is a decision which will be based on the experience of each tumor clinic. As a rule, it may be said that those tumors concerning the cure of which least hope is entertained are the tumors which are treated by means of roentgen rays. Hence, comparison of the value of methods of treatment, roentgenologic or otherwise, should be made only after due consideration of the many factors involved, such as the stage of the disease at the time the patients were encountered, index of the malignancy of the lesion, condition of the patients in the group or groups under consideration, and the like.

Realizing that any classification of tumors with respect to the best method of treatment is subject to great variation in personal opinion, I nevertheless (with more or less trepidation) submit the following classification. Tumors which are placed in one category may, in the opinion of others, belong elsewhere. In fact, some tumors which I regard as being suitable for roentgen ray treatment may be regarded by others as "nonroentgenologic," so to speak. Similarly, the value of various methods of roentgen ray treatment according to my standards is subject to controversy.

1. TUMORS FOR WHICH ROENTGEN RAY TREATMENT IS THE METHOD OF CHOICE

Lymphoblastoma and Leukemia.—Practically all authorities are unanimous in regarding roentgen ray irradiation as the best method of treatment for lymphoblastoma and the various types of leukemia. There is no doubt about the palliation produced by roentgen ray therapy in all cases in this group. Not only does roentgen ray treatment, correctly administered, alleviate symptoms and increase the efficiency of all patients afflicted with lymphoblastoma, but also it may sometimes be a lifesaving measure, and in exceptional cases may produce "cure." Regardless of all refinements of the patho-

logic phase in which the disease is diagnosed, and irrespective of the hematologic observations in a specific case, all types of leukemia and subclassifications of lymphoblastoma probably are best regarded as representing different phases of the same disease, with the same general treatment indicated, and having the same prognosis. Unlike others, I, substantiated by the work of Desjardins, regard this group of tumors as representing a malignant condition, and one in which true cure seldom can be obtained. Since the tumors are characterized by a high radiosensitiveness, the degree of which can be predicted on the basis of the known sensitiveness of the normal cells from which the tumors are derived, it seems to me that application of extreme doses is not indicated in this particular disease. Since, in the average case, the tumor is not confined to a single group of lymph nodes, more or less general treatment would seem to be indicated. Lacking any proof of a contrary view, I favor the use of *"moderate-voltage"* treatment in the average instance of the disease. In my experience the use of such a technic has produced clinical results equal, if not indeed superior, to those produced by other methods of treatment, and it is not accompanied by undue risk and is well tolerated by the average patient.

Since the cause of this group of diseases is unknown, treatment of them has an empiric foundation. The protean manifestations of the various types of lymphoblastoma possibly are less extensive than those of syphilis, and the prognosis after treatment is very variable. In general, *prognosis* would seem to depend on the acuteness or the chronicity of the disease at the time treatment is instituted. No other method of treatment has been so greatly efficient as roentgen ray irradiation, which almost invariably, if correctly administered, palliates symptoms. But in spite of improvement in the patient's condition which often is of long duration, the disease tends to recur, the efficacy of roentgen ray treatment tends to decrease, and in most cases the outcome, after a varying degree of improvement of varying duration in the condition of the patient, is fatal.

Since in our experience the palliation produced by roentgen rays of *moderate* voltage is at least as good as that produced by other methods, and since such irradiation is accompanied by less risk and expense to the average patient, we prefer to employ roentgen rays of moderate, rather than high, voltage for routine treatment in my section at the Clinic. The importance of careful medical supervision in the interval between treatments cannot, according to our experience at the Clinic, be overemphasized. The course of the disease, the pitfalls in the diagnosis and treatment of it, together with indications for the avoidance of such pitfalls, have been dealt with in detail elsewhere, and will not be discussed herein in greater detail at present.

Efficacy of Treatment.—It may be asked "Since roentgen rays can't cure them, what's the use of treating them?" To be fair, the same criterion should be applied to the efficiency of all methods of treatment of all diseases. It must be admitted in fairness that, with the few exceptions in which a specific method of treatment is available, all therapeutic measures are at best only palliative. Strictly speaking, no medical procedure has made man immortal. Therefore, all treatment can be said to be at most palliative. If, therefore, a contrast is made between the course of treated lymphoblastoma and nontreated lymphoblastoma, as judged by results, the value of roentgen ray treatment needs no proof. The average patient who has lymphoblastoma, treated or untreated, dies within three years of the institution of roentgen ray treatment. Nevertheless, patients whose condition is chronic may survive five, ten or more years after roentgen ray treatment, depending on the thoroughness of treatment and the excellence of follow-up care. The comfort and efficiency of all patients are greater after roentgen ray treatment than before, to judge by the experience of all authors.

Carcinoma of the Cervix.—In essentials, the roentgen ray treatment of carcinoma of the cervix is about as follows: Preceding treatment of the cervical lesion with radium, a crossfire of the pelvis directed at the parametrium is outlined

through four to six fields, depending on the size of the patient and the stage and degree of malignancy of the tumor as determined by biopsy and by pelvic examination. The total dose administered to each field, the arrangement of the fields and other details of treatment are not standardized, but are subject to the experience of the individual roentgen therapist. Nearly all authorities decry *preoperative* treatment for carcinoma of the cervix and are in accord with the dictum, "once inoperable, always inoperable." Furthermore, in practically no clinic is treatment of carcinoma of the cervix carried out without both radium and roentgen ray treatment of the primary lesion.

Technical details of both the radium treatment and roentgen ray treatment of carcinoma of the cervix are beyond the scope of this presentation. Nevertheless, regardless of the method of treatment employed, exclusively radiologic treatment in all cases of carcinoma of the cervix will result in an average prolongation of life of five years in about 25 per cent of cases. This figure compared favorably with that for prolongation of life achieved by radical surgical operation in carefully selected cases in which the procedure is carried out by the most expert surgeons. If the physician considers that roentgenologic methods of treatment of carcinoma of the cervix are accompanied by practically no mortality and less morbidity (or at worst, less mortality and morbidity than those which accompany the average surgical treatment) he probably will have little hesitancy in referring his patients suffering from carcinoma of the cervix to the expert radiologist rather than to the expert surgeon. The procedure to be followed in the exceptional case in which the lesion is in an early stage may be divided best on the merits of the facilities available.

In some clinics roentgen therapy is regarded as the method of choice for carcinoma of the cervix, carcinoma of the mouth and carcinoma of the larynx. However, in most centers the best treatment of early lesions in all groups is considered to be surgical, supplemented by judicious treatment with radium. Roentgen therapy is reserved for those lesions which are in-

operable, or which are of the highest grades of malignancy according to the Broders index.

Intra-oral Carcinoma.—Intra-oral carcinoma is another lesion which in some centers is regarded as representing a "non-surgical" disease. Since the radical surgical treatment of most intra-oral lesions involves an extensive, mutilating operation accompanied by a not inconsiderable mortality rate, most conservative surgeons favor reliance on some procedure less radical than complete surgical ablation of the disease, supplemented by interstitial radium and external irradiation by means of radium packs or high-voltage roentgen rays. Modern opinion tends to avoid radical surgical operations for the grade 4 (Broders' classification) intra-oral tumors, and to rely on roentgenologic methods of treatment. Among roentgenologic methods, that of *protracted-fractional treatment* is at present much favored because it seems to offer the best prognosis.

Detailed discussion of the various roentgenologic treatments of the various types of intra-oral carcinoma, their indications, technic and contraindications would lead the reader too far afield, and therefore will be omitted from the present exposition. Regardless of the method of treatment employed, statistics indicate that after patients who have intra-oral cancer are treated by the best clinics 25 per cent of them will survive for five years. In the hands of experts, radiologic treatment in selected cases has produced results about as good as those obtained by expert surgeons in comparable cases. Regardless of statistical results, it would appear that the tendency throughout the world generally is away from the radical surgical treatment of intra-oral carcinoma, and more and more toward radiologic methods. Whether the preferred treatment is a radium or a roentgen ray technic is at present an open question among radiologic specialists. In spite of voluminous literature on the subject, the answer to the problem of the best treatment in a given case of intra-oral carcinoma can be approached after consideration of a multitude of factors by the clinician, the surgeon and the radiologist, and in such a consideration there

are few hard and fast rules to be followed, and few specific indications that are of assistance.

Carcinoma of the Larynx.—Few malignant tumors have been the subjects of as many papers as has been carcinoma of the larynx. Arguments in favor of surgical treatment of this disease have been refuted by as many arguments in favor of radiologic methods. Some enthusiastic and perhaps radically inclined authors have, in fact, advocated no type of surgical operation for any lesion, but rather, complete reliance on roentgen rays or radium. If the working rule is kept in mind that the indications for radiologic methods are indirectly proportional to the skill and experience of the surgeon, the ardor of various authors for various methods of treatment can be more intelligently evaluated. It is an indubitable fact that in certain hands, at least, radiologic methods entail less risk to the patient and offer a better outlook than surgical methods. However, fair comparison of the efficacy of various methods is best obtained by a comparison of the methods in the hands of various equally efficient experts.

From the variety and apparent confusion of opinions stated in the literature the following conclusions (with many reservations) can be advanced: *Intrinsic* operable carcinoma of the larynx is best treated by laryngectomy. Certain operable lesions of the highest degrees of malignancy may best be considered as suitable for radium or roentgen therapy. *Extrinsic* cancer of the larynx, in the opinion of most authors, is best treated roentgenologically or radiologically, and at present the better form of these two methods seems to be protracted-fractional roentgen ray treatment. Statistically, a comparison of results of surgical and radiologic or roentgenologic methods of the treatment of carcinoma of the larynx would have controversial and nonconclusive results.

2. TUMORS IN THE TREATMENT OF WHICH ROENTGEN RAYS ARE BEST COMBINED WITH OTHER METHODS

This group of lesions comprises the great majority of tumors for which patients are referred for roentgen ray treat-

ment. It is in the treatment of these tumors that roentgen rays have their greatest application and in which the exact value of each component used in the treatment as a whole cannot be evaluated exactly. However, it can be stated as a generalization that the value of roentgen rays and their importance in improvement of the (statistical) results of treatment are indirectly proportional to the value of other methods. Regardless of the percentile composition of statistical results, it is the consensus that the average tumor of low radiosensitiveness is best treated surgically and that roentgen rays be used after the operation in the form of a prophylactic procedure. The importance of roentgen rays in this regard is intangible and not subject to correct or accurate evaluation; however, the more closely a tumor approaches inoperability, the greater is the importance of roentgen ray treatment.

Tumors of the Nervous System.—Tumors of the brain, the cerebellum and the whole nervous system, on general principles, should be expected to be radioresistant, since all normal cells and tissues of the nervous system are refractory to roentgen rays. As a working rule, surgical extirpation of all *brain* tumors and other tumors of the nervous system should be advocated. Barring complete surgical removal, biopsy of tissue from the lesion should be conducted to furnish the indications for roentgen ray treatment and to provide a clue to prognosis. The response of tumors of the nervous system to roentgen rays depends on their cellular composition. The more immature and undifferentiated the cells, the higher is their radiosensitiveness and the better in general is the prognosis. Yet in the evaluation of all methods of treatment of tumors of the nervous system, be such methods surgical or radiologic or roentgenologic, it should be remembered that the same type of tumor in various situations has a varying prognosis, and that different tumors in the same situation have a different prognosis. Because of the inherent low radiosensitiveness of all tumors of nervous-tissue origin, the response to roentgen ray therapy by tumors of the nervous system is low. The same general evaluation can be placed on the roentgen ray treatment

of tumors of appendages of the nervous system, such as *pituitary* tumors.

Even though the exact status of the roentgen ray treatment of cerebral tumors has not been established definitely, it seems to be a fact that patients who had tumors of the nervous system and who have undergone *postoperative* roentgen ray treatment as a whole do better than patients who had tumors of the nervous system and who did not undergo postoperative roentgen ray treatment. But because of the numerous variables involved in the clinical evaluation of tumors of the nervous system—even without treatment—the value of roentgen ray treatment for such lesions is at present an open question. Similarly, it is not established which is the best procedure to follow in roentgen ray treatment. Since the tissues of the normal nervous system are known to be comparatively resistant to roentgen rays, and since the most sensitive component type of tissue is the endothelium of the vessels, powerful doses of roentgen rays to the limit of sensitiveness of the vascular system would seem indicated.

At the Clinic, as a result of a somewhat extensive experience with the postoperative roentgen ray treatment of tumors of the nervous system, we have decided to use a six-field crossfire of the patient's head with a dose of about 550 r per field. This dose is repeated at intervals of two months, once or twice, depending on the clinical indications. At present we know of no reason which might cause us to favor protracted-fractional treatment of such tumors with great elevation of the total dose. To date, our experience with such technics has been decidedly unsatisfactory. When the present technic of treatment has been employed, undue reactions of the patient have not been observed. We have not seen the alarming elevation of intracerebral pressure described by others, nor have we encountered injury of the scalp or of the vessels supplying it, or in fact, injury of those supplying the brain. Meanwhile, since the value of postoperative roentgen ray treatment for tumors of the nervous system still is not settled, we can see no reason to

advocate extremely intensive or even radical methods of roentgen ray treatment of such tumors.

Malignant Tumors of the Eye.—Tumors of the eye are uncommon. It probably is a fact that malignant tumors of the *conjunctiva* are the most common of tumors of the eye. As a general rule, they are best treated with lightly filtered radium rather than with roentgen rays because of the technical difficulties involved in treatment. However, after shielding of the eyeball by the insertion of a correctly formed lead plate under the lids, a dose of roentgen rays sufficient to destroy most tumors in this region can be administered without injury to the eyeball. *Melanoma of the retina* is highly malignant and highly resistant to roentgen therapy and is best treated by surgical removal of the contents of the orbit. As a precautionary measure, postoperative roentgen ray treatment should be administered, even though its value is uncertain. Primary tumors of the bone or cartilage of the *orbit* are not suitable for roentgen therapy.

Malignant Tumors of the Salivary Glands.—Primary malignant tumors of the salivary glands, according to the best available evidence, are best extirpated surgically. An exception should be made in *Mikulicz's disease*, which is best regarded as being a form of lymphoblastoma. Tumors of the *carotid body*, according to all authorities, exhibit minimal response to even the highest doses of roentgen rays and thus treatment of such tumors is surgical. *Cystic hygroma*, although it is of low malignancy, is best treated with roentgen rays or radium because of the high incidence of infection which accompanies surgical operation, and the difficulty of complete surgical removal of the lymph-filled cysts.

Metastatic Tumor of the Lymph Nodes of the Neck.—This has been the subject of more radiologic and roentgenologic controversy than perhaps any other type of malignant tumor. Most are highly radioresistant, and the relative values of radical surgical operation and radiologic procedures constitute a question which is still unsettled. Similarly, the status of block dissection still is a matter of opinion. Because of the

inherent resistance of metastatic cancer in the cervical nodes, doses of roentgen rays as high as are consistent with tolerable injury of normal cervical structures seem indicated. Treatment therefore is best carried out by the protracted-fractional technic.

Malignant Tumors of the Thyroid Gland.—Tumors of the thyroid gland seldom are diagnosed preoperatively. After complete surgical removal of the primary tumor, *prophylactic* roentgen ray treatment should be applied to the neck and to the mediastinum. Paradoxically, *interthoracic metastasis* from cancer of the thyroid gland actually is a favorable field for roentgen therapy. As a rule, effusion and the metastatic tumor both disappear after judiciously administered doses of roentgen rays. So far as is known, sufficient evidence is not available to establish the value of roentgen rays as constituting a primary method of treatment of carcinoma of the thyroid gland.

Carcinoma of the Breast.—Roentgen therapy for carcinoma of the breast is a subject worthy of a monograph at least. Since the natural course of an untreated cancer of the breast may involve a long period and since some tumors are relatively benign, any attempts at evaluation of methods of treatment of mammary carcinoma are subject to many instances of exception. It is the universal opinion that the best treatment for an operable carcinoma of the breast is *early and radical surgical operation*. Even though certain workers have produced notable results by roentgen therapy in certain selected cases in which the condition was operable, there are some who regard radiologic and roentgenologic methods of treatment as mere technical exercises, hardly applicable to the general treatment of carcinoma of the breast. To be fair, however, it must be admitted that almost everywhere patients who have cancer and for whom the prognosis is favorable are operated on, and patients who have cancer and for whom the prognosis is unfavorable are treated radiologically. For this reason, exact unbiased evaluation of roentgen therapy or radium therapy and of surgical operation is impossible, because of lack

of sufficiently large groups of strictly comparable cases which might serve in such an evaluation.

Preoperative Roentgen Therapy.—Theoretically, preoperative roentgen ray treatment should be of very high value. However, little incontrovertible evidence in support of this point can be adduced by review of the literature. In the first place, there is little agreement among radiologists and roentgenologists as to the best method of treatment of carcinoma of the breast, either in regard to the distribution of fields or in regard to the dose to be delivered to each field. It is the experience of most clinics that preoperative treatment has not achieved particularly valuable results. Many radiologists and roentgenologists hesitate to take the responsibility of treating a patient whose condition is strictly operable.

Postoperative Roentgen Therapy.—If radical surgical operation for carcinoma of the breast has any justification, and if it does fulfill the ideal of complete removal of all carcinomatous tissue from the field of operation, there is no real need for postoperative roentgen ray treatment, except, perhaps theoretically to destroy cancer cells which might have escaped into the wound during operation. As a result of postoperative observation of many patients who had carcinoma of the breast, my personal opinion is that postoperative roentgen ray treatment in such cases adds little in the matter of improvement to the results of a well-done radical surgical operation. Among patients whom I have treated, the incidence of postoperative recurrence of carcinomatous tissue in the scar or in the axilla, both of which parts have been treated completely by operation, has been low. It is metastasis to the supraclavicular space and to the bones of the spinal column and pelvis which has caused greatest concern. From a theoretic point of view, postoperative roentgen ray irradiation of the spinal column and pelvis is to be advised. Since it has been demonstrated that in carcinoma of the breast the prognosis depends in general on the degree of malignancy of the tumor in the breast and the extent of glandular involvement, the status of roentgen rays in the improvement of the prognosis is uncertain, especially in view

of the well-known variation in clinical malignancy which is manifested by carcinoma of the breast.

Therapeutic Sterilization in Cancer of the Breast.—Lately, much has been written about the value of therapeutic sterilization of women of child-bearing ages who have carcinoma of the breast. There exists, it is true, normal interaction between the breast and the ovary. Nevertheless, this normal relationship is so imperfectly understood that it would be extremely hazardous to postulate the nature of this relationship in the presence of abnormal conditions, specifically, in the presence of carcinoma of the breast. Further, the subject of the normal occurrence in the body of carcinogenic hormones still is too indefinite to permit establishment of the seat of their origin as being either the breast or the ovary. Therapeutic sterilization is to be recommended as a largely theoretic measure.

High-voltage Treatment.—Another open question in the consideration of roentgen ray treatment of cancer of the breast is the use of "high-voltage" (200 kv.) roentgen rays. My view is that as a general rule roentgen rays of such voltage are neither necessary nor indicated. There is no doubt that depth-dose increases as kilovoltage is increased, and that roentgen rays of 200 kv. produce a greater depth absorption than do roentgen rays of moderate voltage. But, since I am convinced that treatment of the lung as a side effect offers little of value in the treatment of postoperative carcinoma of the breast and that it is accompanied by far greater risk to the patient, I do not favor, in any but the very exceptional case, technics in which roentgen rays of 200 kv. are used.

Treatment of Recurrent Cancer.—Postoperative recurrence of cancer in the operative scar is treated well by no known method. In general, if the recurrent tumor can be removed surgically, such a procedure is to be advised. If the recurrent neoplasm is inoperable roentgen ray irradiation remains as a possible measure but the best technic of treatment still is an open question. In general, large doses of "soft" roentgen rays seem to be indicated. But since recurrence after operation and postoperative roentgen ray treatment is evidence of either high

malignancy or high resistance of the tumor to roentgen rays, the efficacy of roentgen rays in the destruction or prevention of further recurrence is doubtful if not minimal.

Treatment of Metastases from Cancer of the Breast.—Roentgen rays constitute the method of choice in the treatment of *osseous* metastasis from cancer of the breast. After correctly administered treatment, pain in the back or in the distribution of the sciatic nerves in most cases is relieved, and provided that the general condition of the patient is not too bad to preclude it, ossification of the metastatic foci in the bones of the spinal column and pelvis commonly occurs.

No one would or does advocate roentgen ray treatment of metastasis from cancer of the breast to the *liver.* As a matter of common experience, it is agreed that the reaction of the patient after adequate treatment of this lesion is too severe and the result too poor to justify continuation of the method.

Metastasis to the *lungs* from cancer of the breast is a process the treatment of which must be decided on the merits of the individual condition. Again as a matter of common experience, it is agreed that roentgen ray treatment will do little more than to relieve pain in this condition and decrease the amount and frequency of the malignant effusion. However, since some tumors of the breast, which unfortunately are unpredictable, have a sensitiveness, which is little less than that of lymphoblastoma, a patient suffering from pulmonary cancerous metastasis deserves to have a course of roentgen ray treatment provided she is in condition to receive it. But in such circumstances moderate doses should be used, with the realization that treatment is at best experimental and of doubtful value.

Metastasis to the *axillary lymph nodes* after postoperative roentgen ray treatment, like metastasis to the supraclavicular lymph nodes, is a bad sign. Roentgen ray treatment, no matter how it is administered in such cases, is at most a palliative procedure of doubtful value. Since the efficacy of postoperative roentgen ray treatment, to judge by the incidence of

recurrence, has been so low, there is little likelihood that additional roentgen ray treatment will be of very great value.

Inoperable Carcinoma of the Breast.—Some types of ulcerated inoperable primary carcinoma of the breast may be well treated by palliative simple removal of the breast, followed by roentgen ray therapy, but since the prognosis obviously is poor in such circumstances, it hardly seems advisable to use such doses as would be applicable to patients for whom there was a better prognosis.

Other types of inoperable carcinoma of the breast may be treated roentgenologically. The choice of method of treatment depends on many factors and is best settled according to the indications in the individual case. Some types of inoperable carcinoma of the breast may receive marked palliation from the insertion of radium needles, supplemented by the administration of roentgen rays. In our experience at the Clinic, treatment by the "method of multiple converging beams" has produced the best results. After such treatment pain is relieved, discharge is lessened and the local condition of the patient is improved. It is not at all uncommon after adequate treatment for ulcers to heal and as a result the patient enjoys a period of palliation welcomed by both herself and her relatives. Provided she is in condition to endure it, we of the Section on Therapeutic Roentgenology feel that every patient who has inoperable carcinoma of the breast deserves to have the benefit of at least one mild course of roentgen ray treatment.

Bronchiogenic Carcinoma.—Theoretically, *pneumonectomy* offers the patient suffering from primary bronchiogenic carcinoma the best chance for permanent cure, provided that he or she survives the operation, which even in the most expert hands still is accompanied by a formidable mortality rate. Radical operation as a rule is reserved for those patients who are in good physical condition, who have a relatively small localized tumor, and who are willing to sustain the risk associated with pneumonectomy. *Roentgen ray treatment*, on the other hand, usually is administered in those cases in which the

outlook is less favorable or in which the patients are unfitted for radical operation or refuse it. Therefore, fair comparison of the value of roentgen rays and surgery in the treatment of bronchiogenic cancer is difficult, for, obviously, the conditions of patients who have operable lesions and patients who have inoperable lesions are not comparable. Regardless of the status of the patients and the technics by means of which they were treated, evidence has been adduced recently to show that the length of life of the patient who has untreated cancer of the bronchi (the usual length of life in such cases is at most a year after proof of the diagnosis) in most instances may be increased more than a year by roentgen ray therapy.

Malignant Tumors of the Kidney.—The normal kidney ranks high among tissues which are resistant to roentgen rays. It could be predicted, therefore, that tumors of the kidney would not be suitable for roentgen ray treatment. Such is indeed the case, to judge by the published results of roentgen ray treatment. Most authors agree that once the diagnosis of tumor of the kidney has been established positively, the best treatment for the patient is *nephrectomy*. However, recent works on the preoperative roentgen ray treatment seem to show that such therapy improves the prognosis in instances of renal tumor in which the outlook is grave, once the diagnosis has been definitely established, no matter how the patient is treated thereafter.

One type of tumor of the kidney deserves special attention. This is the *embryonal carcinoma* of the kidney, commonly known as "Wilms' tumor." The extreme radiosensitiveness of this tumor among children often serves as an important point in the differential diagnosis, and greatly assists in the distinction of this lesion from other swellings of the kidney. The rapid regression of this tumor after the administration of moderate or even mild doses of roentgen rays is one of its characteristics. However, the course of this tumor illustrates only too well the fact that radiosensitiveness does not assure curability, for the known cures of this tumor after roentgen therapy with or without surgical operation are so few as to be

practically nonexistent. Whether or not refinements of roentgen ray technic in the future will improve the poor end results of treatment of this highly radiosensitive tumor is a question for speculation and hope.

Hypernephroma is a collective term applicable to tumors of the kidney and suprarenal gland without much attention being given to the true nature of the lesion. Since it is agreed that the normal suprarenal gland offers the highest resistance to roentgen rays, the prediction that suprarenal tumors will not regress after roentgen ray treatment is substantiated by the experience of most authors.

Carcinoma of the Bladder.—The experience of most roentgen therapists in the treatment of cancer of the bladder is too limited to permit formation of conclusions as to the importance or the actual value of the method. However, all investigators seem to be agreed that a patient who has tumor of the bladder scarred by diathermy or operative procedures or by the insertion of radium does not do so well after roentgen ray treatment as a patient who has a comparable tumor that has not been so treated. Most authors seem to regard carcinoma of the bladder as a fairly radiosensitive lesion. Yet, in the question as to the best method of treatment for this lesion there is little to be said. My own personal experience causes me to tend to oppose protracted-fractional roentgen ray treatment and to favor milder methods.

Malignant Tumors of the Testis.—Ordinarily, tumors of the testis are called "teratomas." The term is a poor one because much evidence exists which seems to prove that the most common tumor of the testis is the *seminoma*, or *embryonal carcinoma*, and that as a matter of fact, true teratoma is rare. Much has been written about the importance of the hormonal relationships of testicular tumors, but a critical analysis of the evidence assigned to such relationships would reveal little that is of diagnostic or prognostic significance. Seminoma of the testis has one important characteristic: it is highly sensitive to roentgen rays. High radiosensitiveness is to be expected of this tumor, since the normal cells from which it is derived are

themselves highly radiosensitive. Opinion as to the best treatment for tumors of the testis is at present unsettled. Many authors seem to doubt the advisability of orchidectomy, in view of the fact that the primary testicular tumor usually can be treated satisfactorily by roentgen rays which treatment is accompanied by no danger whatever of injury of the other (normal) testis. There seems to be little justification for the surgical practice of excision of a testis in cases in which abdominal metastasis has occurred. In connection with the clinical phases of intra-abdominal metastasis from testicular tumors, the reader is referred to the excellent exposition of the subject in the many papers of Desjardins.

The *prognosis* in seminoma of the testis after administration of roentgen ray therapy, if abdominal metastasis is not present, is such that about 60 per cent of patients so treated will survive for five years. If, on the contrary, retroperitoneal metastasis has taken place at the time roentgen ray treatment is administered, the best results that can be expected are that about 30 per cent of such patients will survive for five years. The importance of early treatment in the presence of this lesion is therefore evident.

Points in Treatment.—A few points should be emphasized concerning the roentgen ray treatment of tumors of the testis. True teratoma and true carcinoma of the testis are rare, as has been mentioned previously. When they have been proved to be present, radical and intensive roentgen ray treatment is indicated on general principles. If percentage based on incidence is accepted as being important in the diagnosis of testicular tumors, the statistical chances are that a tumor of unknown nature will be a seminoma. The response of the lesion to roentgen ray treatment will verify or nullify the tentative diagnosis. Since the mode of spread and the time relationships of metastasis of seminoma of the testis are definitely known, it seems to me, at least, a waste of time to devote maximal attention to irradiation of the groin on the homologous side of the tumor, a technic which seems to be in common use. It does not seem wise to me to administer doses of high-

voltage roentgen rays, which produce maximal systemic injury, in the treatment of a lesion which is characterized by extreme radiosensitiveness. As a matter of fact, published results of the treatment of testicular seminoma by radium and high-voltage roentgen rays, are not superior to those obtained by milder treatment.

Malignant Tumors of the Ovary.—For reasons that are not apparent, the radiosensitiveness of tumors of the ovary is *not in accordance* with the radiosensitiveness which would be predicted on the basis of the radiosensitiveness of the normal ovary. The factors which cause this apparent contradiction are uncertain and largely unknown. That the normal ovary is extremely sensitive to roentgen rays is universally agreed. As a result of this knowledge, the production of undesired roentgenologic effects on the ovary is carefully avoided by all roentgen therapists when fields which may include the ovary are irradiated for any reason. Menstrual disturbances of some degree unfortunately are common after irradiation of pelvic lesions, in spite of all precautions. Ovarian tumors, contrary to expectation, generally are of indifferent if not indeed minimal radiosensitiveness.

Such a state of circumstances is due, in a way, perhaps, to the uncertainty of the nature of a given ovarian tumor when the patient presents herself for roentgen ray therapy because of the multiplicity of the pathologic classifications of ovarian tumors. As a result of this situation a roentgen therapist naturally is much hampered in his attempt to base his dosage on the theoretical radiosensitiveness of the given tumor. As a whole, then, treatment of ovarian tumors is most conservatively regarded as being primarily *surgical*. The prognosis may be improved by postoperative roentgen ray treatment of the pelvic viscera. Much recent literature seems to emphasize the value of *postoperative* roentgen ray treatment, but to date the details of such treatment are subject to many individual variations depending on the individual roentgenologist.

Malignant Tumors of Bone.—It is a maxim in therapeutic roentgenology that if a tumor of bone responds to roent-

gen ray or radium treatment, the tumor cannot be an *osteogenic sarcoma*. On the other hand, the high radiosensitiveness of *endothelioma* of bone is universally recognized. Therefore, the response of a questionable tumor of bone to roentgen ray treatment may provide differential diagnostic indications of inestimable importance. The same is true of the roentgen ray treatment of malignant central *sarcomas* in distinction to benign giant cell tumors, the latter of which usually respond well to roentgen ray treatment. The whole field of treatment for tumors of bone is in such a state of uncertainty clinically that it is not possible, on the basis of established fact, to advocate either surgical operation or roentgen therapy, alone or in combination, in the treatment of malignant tumors of bone. In this field, as in probably no other, much confusion exists in regard to both pathologic classification of the lesions and indications for the various methods of treatment of the lesions.

Carcinoma of the Rectum.—Recent work has tended to show the great value of *radium treatment* as an adjunct to radical surgical treatment for carcinoma of the rectum. Some tumors operable in every sense have been cured by radium therapy alone, and as a result the usual surgical treatment has been found to be unnecessary. It must be admitted, however, that roentgen therapy, no matter what the dose has been, has been found to be of questionable value as a primary curative procedure. Whether future developments in the application of roentgen rays will augment their importance is a question which the future alone can decide.

3. TUMORS IN THE TREATMENT OF WHICH ROENTGEN RAYS ARE OF QUESTIONABLE OR NO VALUE

On general principles it can be stated that tumors derived from normal cells of the lowest sensitiveness to roentgen rays cannot be treated successfully with such rays. This assumption is in fact supported by general clinical experience. There is a group of tumors, some of which are of rare occurrence it is true, for which roentgen ray treatment to all practical purposes can be regarded as useless. In the present state of

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knowledge, roentgen ray treatment of *carcinoma of the gastro-intestinal tract,* with the possible exception of cancer of the rectum and colon as previously noted, can be considered to be useless. This comparative uselessness arises from the fact of the resistance of gastro-intestinal carcinoma to roentgen rays and the comparative sensitiveness of the normal surrounding structures to roentgen rays. For this reason, it is technically impossible to produce a satisfactory effect on a gastro-intestinal tumor without coincident severe injury to normal structures, the radiosensitiveness of which is comparatively great.

Roentgen ray treatment also is of questionable value in the treatment of *carcinoma of the fundus of the uterus.* The best treatment for this condition, according to all authorities, is primarily surgical. The value of roentgen rays in the destruction of cells which have escaped from the uterus into the parametrium seems to be more theoretic than actual.

Most gynecologists agree that *fibroid tumors* are best treated according to the indications found at exploratory operation, whether the findings indicate myomectomy or hysterectomy. However, in certain cases in which operation is contraindicated, a "menopause dose" of roentgen rays has produced the desired clinical regression of the uterine tumor. Even though some authorities have insisted that all treatment of fibroid tumors always be carried out by means of roentgen rays, there are others of equal eminence who insist that the primary treatment should be surgical. Since the application of both methods entails minimal risk to the patient and since both methods produce results which generally are satisfactory, it must in truth be stated that in the treatment of fibroid tumors roentgen rays are of questionable value. In this connection the word "questionable" should be interpreted to mean "unestablished," with reference to the importance of other methods of treatment.

It was stated previously herein that if a *tumor of bone* will regress under roentgen ray treatment it cannot be a true osteogenic sarcoma. Cure by roentgen ray treatment alone in a case of proved malignant *periosteal sarcoma* is, so far as I

know, unknown. The value of roentgen therapy as a prophylactic measure *after amputation* also is questionable.

Many observers feel that *Ewing's tumor* (endothelioma of bone) is a specialized form of lymphoblastoma, in much the same sense that the various types of leukemia are so regarded. At any rate, this tumor is characterized by its high radiosensitiveness. This characteristic is of great importance in the distinction of this lesion from other osseous lesions in those cases in which the roentgenologic and histopathologic observations are obscure or inconclusive. In the treatment of this lesion the importance of operation and of irradiation is still the subject of much controversy. Because of the high radiosensitiveness of this tumor, extreme doses of roentgen rays are not necessary or desirable, especially because of the possibility of production of injury to the growing bones of the young patients whom this lesion commonly afflicts. In spite of complete local control of the tumor which is possible by means of administration of roentgen rays, the disease usually is fatal because of metastasis to the lung. From a palliative, rather than a curative, point of view the importance of administration of roentgen rays in this condition is outstanding; in exceptional cases roentgen ray treatment alone may result in "cure."

Malignant melanoma and its related type of tumor, *fibrosarcoma*, are in the experience of most roentgenologists among the least favorable tumors for roentgen ray therapy. If a favorable clinical response is noted in the treatment of an alleged malignant melanoma, the observer would be constrained to question the diagnosis. Definite distinction must be made between a benign mole and a malignant melanoma. In spite of temporary regression of a melanoma after roentgen ray treatment, the lesion must be regarded as being extremely malignant and not radiosensitive, and, as a rule, as causing death. The same point of view must be adopted in regard to the roentgen ray treatment of fibrosarcoma of soft tissues.

The experience of most roentgen therapists with the roentgen ray treatment of *carcinoma of the prostate gland* has been unsatisfactory. However, the analgesic effect of roentgen ray

irradiation in this condition makes a trial of such treatment worthwhile.

4. TUMORS THE TREATMENT OF WHICH WITH ROENTGEN RAYS IS EXPERIMENTAL

In this category must be included all tumors subjected to supervoltage roentgen ray treatment. If it is admitted that patients so treated are beyond hope of benefit from the ordinary methods of treatment, the lack of favorable response so commonly reported after supervoltage roentgen ray treatment can be explained easily. The theoretic advantages of administration of extremely "hard" roentgen rays, as far as clinical reports are concerned, are still not outstanding. The same point of view obtains in evaluation of results of treatment by artificially created radioactive substances.

COMMENT

I have tried to emphasize the fact that roentgen ray treatment alone is advisable only occasionally, and that in fact there are certain definite limitations to its application which I have tried to point out herein. To complete the present exposition logically it must be admitted that there are certain definite contraindications to roentgen ray treatment itself. Among these may be mentioned undoubted operability of the lesion, advanced cachexia of the patient, the presence of multiple metastasis, demonstration of a tumor of known excessive radioresistance, and finally, rare instances in which extensive widely disseminated tumor is present but in which the patient remains in comparatively good condition.

In the planning of roentgen ray treatment for a given patient who has a given lesion, the primary question which the roentgenologist should answer for himself is, "Can I, if I am fortunate, cure this patient?" If the answer is in the affirmative no effort should be spared to administer sufficient treatment to the patient, even at the expense of production of some bodily injury. But the intensity of this dose should be decided only after most careful analysis of the radiosensitiveness of the

tumor involved and the regenerative powers of the patient. In the final analysis, the reactivity of the patient is the most important point of consideration, and yet the most indefinable factor. No physician in the world wishes to kill both a tumor and the patient who has it. Yet this can be done if roentgen ray treatment is incorrectly administered.

In most cases, however, the question is not one of cure, but of palliation, and the question to be answered is not how much, but how little, treatment will obtain for the patient the best result after due consideration has been made of the disturbance, if not actual misery, the patient will sustain in such treatment and also the expense the patient will have to meet.

CONCLUSIONS

The roentgenologist should ask himself the question which the visiting physician asks, much to the embarrassment of the roentgenologist: "Exactly what is roentgen ray treatment good for?" The answer to this question is contained in the problem which should urge the roentgenologist to strive for better results by the employment of better methods of treatment. However, the fact should be kept constantly in mind that the rationale of roentgen therapy for malignant tumors still is purely empirical since neither the exact nature of tumors nor the exact effect on them is known, that probably neither the roentgen nor the angstrom is the answer to the problem of cancer, and that no method of roentgenologic or radium treatment has been proved to cure 51 per cent of tumors as they are encountered in practice. For in truth, the problem of the average roentgenologist has not been radically simplified by progress in the early diagnosis of malignant tumors, for his daily work is now, just as it has been for the past twenty years, not the cure, but the palliation, of cancer which is usually in advanced stage by the time he encounters the patient.

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ROENTGENOLOGIC RISKS SUSTAINED BY THE PHYSICIAN NOT TRAINED IN ROENTGENOLOGY

EUGENE T. LEDDY

All informed physicians recognize roentgenologic examination as an invaluable method of diagnosis in both medical and surgical practice. Recent propaganda tends to emphasize this importance of roentgenology to the extent that many conscientious physicians who lack roentgenologic equipment of their own may be led to doubt their ability to carry out honest, complete and conclusive examinations of their patients without such equipment. In practically all American medical journals, advertisements, which usually are embellished by reproductions of technically perfect roentgenograms, urge the purchase of roentgenologic equipment.

But nowhere in the advertising is the physician made acquainted with the risks to himself that the operation of his own roentgenologic equipment may entail. Nor do the medical texts contain much information about these risks or how they can be minimized or avoided altogether. Obviously it is not the function of the manufacturers of roentgenologic equipment to teach physicians how to operate the apparatus any more than it is that of manufacturers of automobiles to teach purchasers to drive. The toll of operators' life and limb in both cases is attributed to lack of training or experience or to indifference or carelessness on the part of those same operators.

If it is permissible to judge from the physician patients encountered at one clinic, more and more physicians are sustaining injury from the operation of their own roentgenologic equipment. In the years 1919 to 1939 inclusive, 135 physicians came to the Mayo Clinic for advice about, or treatment of, injuries which they had sustained from roentgen rays and

which usually were of the severest types. For the purpose of analysis, which has been presented in detail elsewhere, only cases in which the severest injuries had occurred were included: seventy-two cases of severe *telangiectasis* and *keratosis*, twenty-four cases of *ulcer* and thirty-nine cases of proved *epithelioma*. It should be kept in mind that all these injuries were self-inflicted and were the result, in most cases, of roentgenologic examination of patients by the physicians concerned, only eight of whom had had any special roentgenologic training. All of the eight just mentioned were roentgenologists, but none of them had used the recommended methods of protection until after they had been injured. The most common *sites* of injury were the backs of the fingers and hands, and of the fingers the left index was the most frequently and most severely damaged. The face and eyes were, surprisingly, comparatively free from injury.

Actually more physicians are being seen each year because of injuries from radiation. This may be the result of one of three factors: (1) more physicians than formerly may be coming to the Clinic for consultation, (2) an increased number of physicians may be acquiring radiodermatitis, (3) possibly the diagnosis of radiodermatitis is being made more often than it used to be made. Be these considerations as they may, it seems logical to explain the increase by saying that more physicians than formerly actually are receiving injuries from roentgen rays. It is impossible to state whether the injuries encountered, although of recent appearance were, in some cases, the result of cumulative overdosage for a period of years. In some instances, however, the injuries were the result of a single overdose sustained during one examination.

Because so many of these self-sustained injuries are manifested by physicians with little training who "do a little *x*-ray work" on fractures or use roentgen rays otherwise in their practices, one wonders what the incidence of injury in the future may be, and how these injuries may be prevented or minimized. Until recently a saving feature has been that efficient apparatus has been rather expensive. But hesitation

on the physician's part to purchase roentgenologic apparatus seems to be disappearing. For this reason, unless information concerning the dangers and methods of protection against them are widely disseminated, a considerably higher incidence of roentgenologic injuries is to be expected in the future than has been obtained in the past.

The Roentgenoscopic Reduction of Fractures.—Reduction of fractures by means of roentgenoscopy was the maneuver in the course of which ninety-one of the 135 physicians were injured. The shocking fact came to light that seventy-eight of the physicians who injured themselves in this way had not used protection of any kind, and that thirteen others had used lead rubber gloves only after the injury had become apparent. Some of these physicians thought the dermatitis was of an allergic nature or that it was caused by soaps or disinfecting solutions used in the operating room; even then they did not wear protecting gloves, but spared the injured hand and subjected the other hand to damaging doses of roentgen rays. Other physicians sustained severe radiodermatitis from a single examination, made in most cases shortly after installation of the roentgenologic equipment.

The *backs of the fingers and hands* are most severely injured during roentgenoscopic reduction of a fracture because these parts lie nearest the roentgen tube. During manipulation and reduction of a fracture, the thumb of the operator is protected by the limb of the patient which intervenes between the operator's fingers and his thumb. Since some fractures are difficult to reduce and to maintain in apposition, it is not at all unusual for an operator who is indifferent to the radiation output of his machine *to run it* for twenty minutes or more and in this way to subject his fingers, and perhaps also the limb of the patient, to many times the safe dose in a single exposure. Or else a physician who does considerable fracture work may be injured because he exposes himself too frequently to doses which may be safe in themselves, but the effect of which accumulates, because of incomplete recovery of the injured part, until severe injury is produced.

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visual adaptation. But, above all things, impatience should be avoided. Correctly adapted eyes permit visualization of the limb and its manipulation with the lowest (and therefore safest) factors governing intensity of roentgen rays.

In spite of their clumsiness and bulkiness and general inconvenience, *lead rubber gloves* should be worn during all stages of the reduction of fractures under the fluoroscope. This single expedient—the wearing of lead rubber gloves—is the most important protective measure which the operator can use and it should be used in every case without exception. Theoretically, mechanical manipulation of the fractured limb should be substituted for manual methods wherever possible. However, the use of this safety procedure is of importance secondary to those mentioned. The adoption of a technic of making roentgenograms rapidly in the operating room is to be recommended to those whose work entails frequent reduction of fractures and to those to whom adoption of the means of protection outlined above seems too much trouble.

If it is at all possible, the roentgenoscopic reduction of fractures should be carried out under the supervision of a roentgenologist. This advice applies rather less to the general practitioner than to interns, surgeons, orthopedists and others, unless they have had special training in this roentgenologic phase of their specialties. But all users of roentgen rays should employ a careful technic, which includes appropriate emphasis on the dangers of an uncontrolled or bungling examination.

Roentgenoscopic Examination of the Thoracic Organs or the Gastro-intestinal Tract.—The second greatest cause of injury to the physicians in the group under consideration was roentgenoscopic examination of the thoracic organs or of the gastro-intestinal tract. These procedures accounted for twenty-one severe injuries in a study already reported. It is not necessary at this time to discuss in detail the *faults of technic* by which a careless or inexperienced operator may exceed the limits of safety to himself. They may, however, be summarized as follows: (1) lack of a technic of examination; (2) excessive "puttering around"; (3) incomplete adaptation

Even though reduction of fractures is a common procedure, mentioned in almost all modern surgical and orthopedic texts, surprisingly little that is specific has been written about the possibility of self-injury by use of the roentgenoscope, and almost no specific directions have been given as to how to avoid such injury. Some authors do, it is true, make more or less general recommendations but they are made usually rather from a surgical than a roentgenologic point of view.

Since the general practitioner is the one most commonly called on to treat patients with all but the severest or most complicated fractures and since he is often called in emergency, a few remarks about his self-protection should be in order at this point.

Considerations in the Reduction of Risks.—The operator of the roentgenologic machine used for examination should know definitely how great is its *output* of roentgen rays. Further, he should know how long it takes the machine, in operation, to reach an output of roentgen rays that represents the limit of safety to the skin. Such data need not be determined by the operator, but can be obtained from the manufacturer of the apparatus and in general are valid until a new roentgen tube is installed or until some electrical change is made. Next, a *filter* equivalent to at least 1 mm. of aluminum should be installed in the tube holder, below the tube. This filter should never be removed as it is a protective device of inestimable importance. Next, the operator should determine what arrangement of the *physical controls* permits satisfactory visualization of the fracture with the lowest possible roentgen intensity. In the solution of this problem, the advice and help of an experienced roentgenologist are invaluable.

Of equal importance in the technic of safe roentgenoscopic examination is *thorough adaptation of the eyes to darkness.* This may require waiting fifteen or more minutes in total darkness for the eyes to adapt themselves, and can rarely be accomplished while the operator takes a few puffs of a cigaret, or walks around impatiently while things are being made ready for the examination. Specific directions cannot be given for

of injury sustained by the roentgenologic specialist are negligible in contrast to the high risk run by the casual user of roentgenologic equipment. Yet there seems to be no easy way to impress on physicians of the latter group the risks which careless or indiscriminate use of roentgen rays involve. Only rarely do these physicians read roentgenologic journals, which seem to be the logical places to disseminate roentgenologic information. The other medical journals have abundant material of greater general interest and do not feel justified in devoting much space to such a lugubrious subject as roentgenologic injuries. Perhaps the medical school is the best place to emphasize the risks, for it is there that the physician is first impressed with the importance of roentgenologic examinations. It seems sensible, also, to teach the student how to use roentgenologic equipment, just as he is taught to use other diagnostic apparatus. Everyone knows that not all students who have had training in pathologic technic and who understand the microscope become pathologists, nor do all who can use the electrocardiograph become cardiologists, nor do more than a small fraction of those trained in the use of the knife become surgeons. Certainly the same importance can be given to instruction in roentgenology and to the risks it entails.

The texts the physician uses before and after graduation should devote more attention to specific protection in the various roentgenologic procedures he is likely to adopt in practice instead of mentioning them only casually and rarely. Most of all, the physician untrained in roentgenology should be urged to avoid roentgenologic examinations in all but the exceptional or emergency case and, as far as possible, to refer patients to a roentgenologist for the appropriate roentgenologic examinations. He should not sustain, himself, the expense involved in purchase of a machine and the risks of operating it.

of the eyes to darkness; (4) too great current and voltage; (5) installation of insufficient filtration in the roentgenologic apparatus; (6) use of too large fields; (7) placing the bare hands in the field; (8) lack of lead rubber protecting gloves; (9) needless exposure, such as holding the casette during bedside examination of a patient, while a nurse or some other person manipulates the controls of the machine; (10) inattention to the time that the roentgen tube has been in operation; (11) ignorance of the protecting devices advocated by the safety committees.

One reason why fewer physicians were injured in the course of the type of study mentioned in the preceding paragraph than were injured during reduction of fractures, is that roentgenologic studies of gastro-intestinal and thoracic diseases are less often attempted by those untrained to make them than is true in relation to manipulation of fractures.

Post-irradiation Carcinoma.—Aside from calling attention to the incidence of thirty-nine cases of carcinoma as a result of excessive exposure to roentgen rays among the 135 physicians considered, there is little to be said concerning carcinoma. These cases, however, should serve as a warning to those who imagine that roentgenologic technic is easily acquired and the thirty-nine physicians who produced cancers in themselves by using their own apparatus, no matter how well those particular men may have used it, should serve as impressive proof of the dangers inherent in unskilled roentgenologic examinations.

Comment.—It should not be inferred from the foregoing that the general practitioner is the only one who risks injury by using his own roentgenologic apparatus. More of them were encountered in the group studied because more general practitioners than specialists came to the Clinic for advice or treatment. Some dentists, general surgeons, orthopedists, chest specialists and gastro-enterologists also were severely injured as well as some roentgenologists; these last already have been discussed briefly.

Elsewhere it has been pointed out repeatedly that the risks

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ROENTGENOLOGIC PELVIMETRY

C. ALLEN GOOD

The use of roentgenograms to measure the bony pelvis is not a new procedure. As long ago as 1899 Albert attempted to measure the maternal pelvis by means of the x-ray. The early methods were crude and the measurements were not as reliable as those obtained by the obstetrician. With improvement of radiographic equipment, new methods of greater accuracy were developed. Today many methods are in use which are capable of measuring the pelvic diameters with an error no greater than 3 mm.[12, 17] Discussion and analysis of the various technics of roentgenologic pelvimetry may be found in the excellent review of Hodges and Dippel.

Because of the outstanding work of Caldwell and Moloy and their co-workers[2, 3, 4, 10] and of Thoms,[20] it is now recognized that the *shape* of the female pelvis varies greatly. Thoms described the inlet as ranging from a long oval to a wide oval. Caldwell and Moloy included also a triangular or blunt heart-shaped inlet. They emphasized the fact that variation in shape influences the mechanism of labor,[5, 6, 7, 8, 11] and they expressed the opinion that roentgenologic pelvimetry aids the obstetrician in planning the method of delivery.

The Maternal Birth Canal.—The birth canal may be thought of as a curved tunnel. The entrance to this tunnel is the *obstetric inlet*, a plane bounded entirely by the bony contours of the pelvis near the plane of the superior strait. The walls of the tunnel are more or less irregular and are made up of various portions of the bony pelvis together with certain ligaments and muscles. The exit from this tunnel is the

aras, especially when the breech presents, (3) during labor, to ascertain the site of arrest and to aid in planning measures to overcome the dystocia, (4) when the patient requests the examination.

THE METHOD

There are many methods of roentgenologic pelvimetry in use today. It is not the purpose of this article to describe or evaluate them. Some, especially the stereoscopic method employed by Caldwell and Moloy,[9, 18] are extremely accurate in the proper hands but require special equipment. Others sacrifice accuracy for simplicity. The method to be described requires only equipment found in the ordinary roentgenographic laboratory together with a few easily made tools. This method is not original but has been assembled from the works of various authors, notably Thoms and his co-workers.[21, 22, 23, 24] It is at once simple and sufficiently accurate for ordinary work.

Films of the maternal pelvis in three projections are obtained: (1) a film of the inlet, (2) a lateral view and (3) a film of the subpubic arch. From these films the pelvis is classified according to the method of Caldwell and Moloy,[3, 10] variations in pelvic structure are noted, and measurements of certain pelvic diameters are made. From this information a prediction as to the course and outcome of labor is offered.

Equipment Needed.—(1) A metal rule (Fig. 77, *a*) notched at centimeter intervals. This is made easily by obtaining a short brass strip and filing notches 1 cm. apart. (2) A back rest (Fig. 77, *b*), preferably one which can be adjusted. In lieu of a back rest a chair may serve. It is placed upside down upon the radiographic table in such a manner that the patient rests her back against the back of the chair. (3) Any radiographic table equipped with a Bucky-Potter diaphragm. It is advantageous if the table also tilts to 90 degrees.

Calibration of Equipment.—Before measurements of the various diameters of the inlet can be obtained it is necessary to calibrate the equipment. This is done by placing the notched metal rule parallel to the table top at various levels, and exposing the film with the central ray striking the film perpendicu-

obstetric outlet which is a combination of two plane triangles joined together at their bases. Two sides of the anterior triangle are formed by the bones of the subpubic arch while two sides of the posterior triangle are made up of soft parts connecting three bony points, the two ischial tuberosities and the tip of the sacrum.

Variations in Shape.—Many variations in the shape of this tunnel are possible. It may be roughly cylindrical, with similar diameters throughout. It may be narrowest at the entrance and gradually become larger toward the exit. It may taper from entrance to exit like a funnel, or it may become narrow in its midportion like an hourglass. The entrance, the exit, or any cross section of the tunnel may be round, oval or roughly triangular.

INDICATIONS

In many instances the obstetrician obtains sufficient information from his own measurements to predict the course and outcome of labor. Roentgenologic pelvimetry does not take the place of the obstetric examination; rather it supplements and corroborates it. There are times, however, when the obstetrician cannot make a satisfactory examination: (1) when the vaginal examination is contraindicated owing to the precaution of asepsis when the patient has presented herself too late in pregnancy, or (2) when the patient is extremely obese. At such times, the roentgenologist is able to offer an accurate analysis of the pelvic structure.

Roentgenologic pelvimetry also is indicated whenever the clinical examination suggests an abnormality in the size or shape of the pelvis. The roentgenograms form a permanent record of the abnormality and usually aid in the formulation of plans for delivery. In a similar way it is well to obtain pelvimetric analysis by the roentgenologist in all cases in which the patient gives a history of dystocia at a previous delivery especially if fetal death or maternal injury occurred, and whether or not the results of obstetric examination are normal.

Additional indications for roentgenologic pelvimetry are found (1) in cases of fractured pelvis, (2) in elderly primip-

metal rule are obtained on film, these images being distorted in the same amount as any object which lies in the plane at that distance from the table top. For ordinary purposes films taken with the rule lying parallel to the table at each centimeter from 5 to 18 will suffice. These film rules should be marked to show their distance from the top of the table (Fig. 78). They serve for all cases until the equipment is changed.

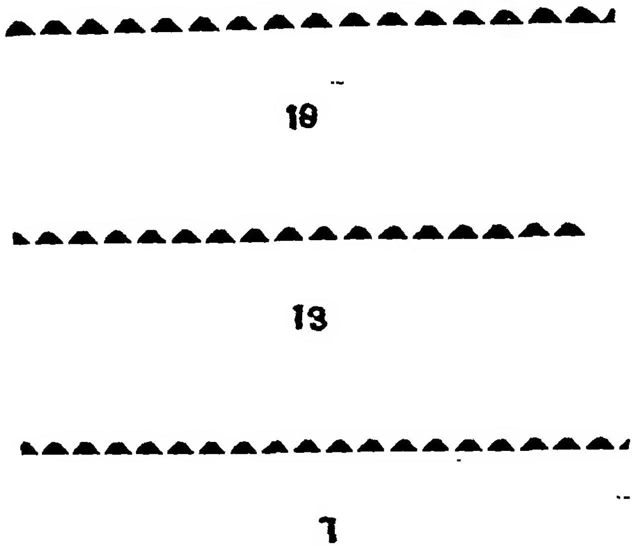
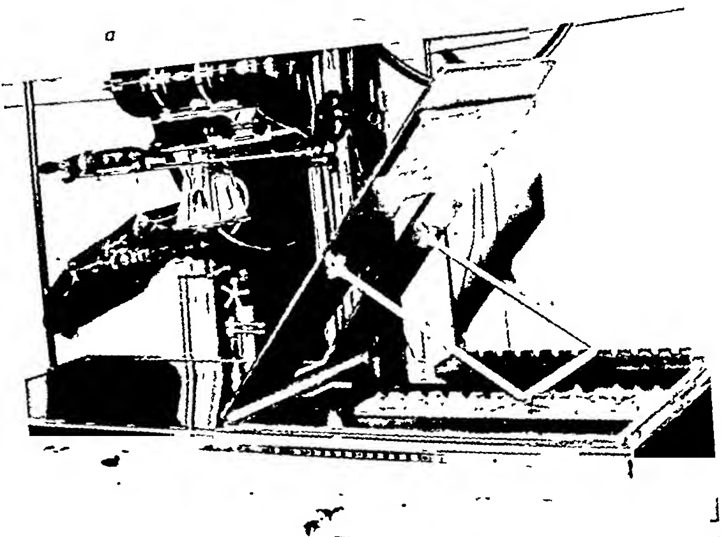


Fig. 78.—Reproductions of three film rulers obtained by radiographing the notched metal centimeter rule placed parallel to the table top at distances of 19 cm., 13 cm. and 7 cm. Note the variation in size of the centimeter intervals.

Technic.—*Film of Inlet.*—After disrobing, the patient puts on a cotton gown or sheet which is open in back. A mark is made with a wax pencil over the spinous process of the fourth lumbar vertebra. The patient then sits on the radiographic table leaning against the back rest which is at an angle of about 60 degrees from the horizontal. The distances are measured (1) from the table top to the superior border of the symphysis pubis and (2) from the table top to the mark on the back which represents the spinous process of the fourth lumbar

a



b

Fig. 77.—*a*, Metal rule notched at centimeter intervals. The handle fits into an ordinary adjustable clamp stand. *b*, Adjustable back rest in place on radiographic table. The cut-out center portion is necessary for proper measurement of the distance from the table top to the mark on the back over the spinous process of the fourth lumbar vertebra.

larly. The target film distance must be the same as that used in making the film of the inlet. In this manner images of the

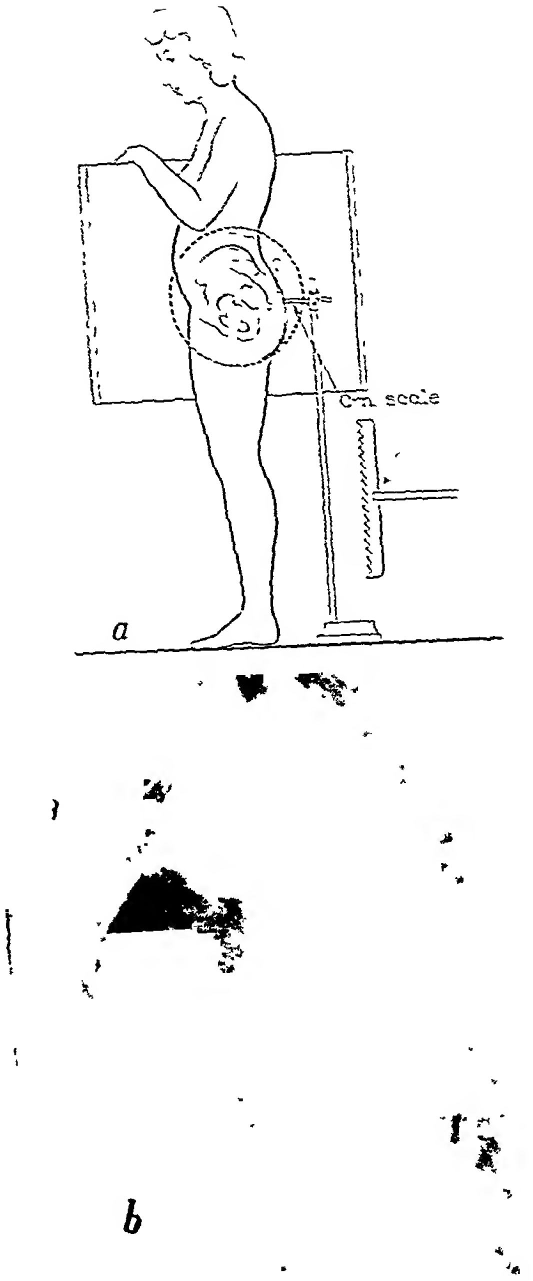


Fig. 80.—a, Position of patient used to obtain lateral roentgenogram of pelvis. Note position of notched metal centimeter rule in midsagittal plane. b, Lateral roentgenogram of pelvis obtained by using position indicated in a.

vertebra. The position of the patient then is adjusted by means of the back rest until these two distances are equal. It

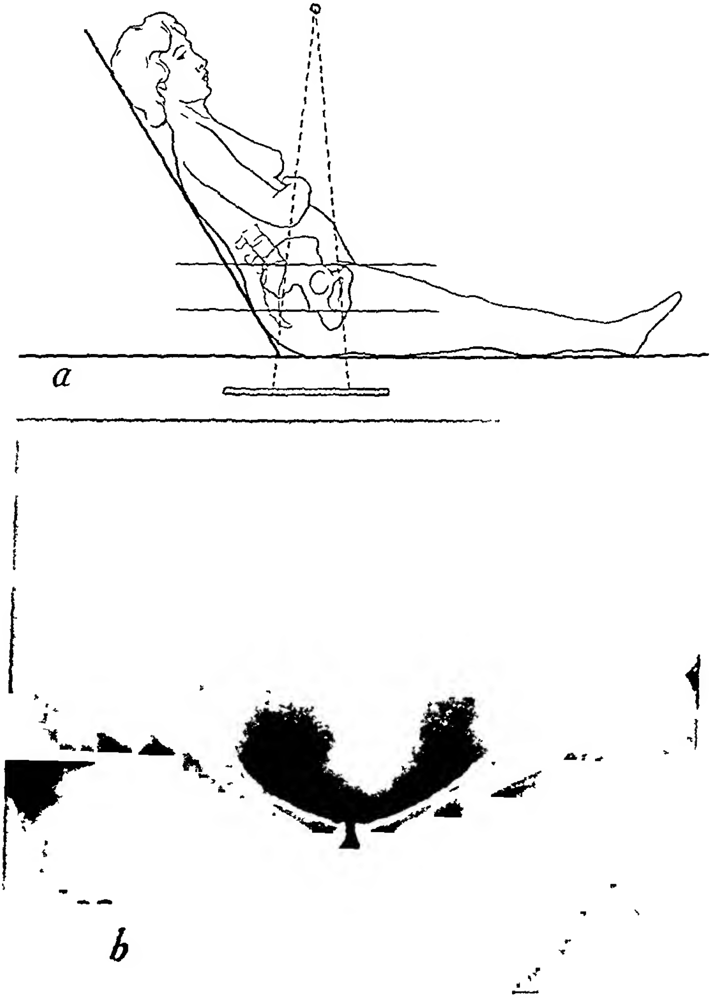


Fig. 79.—a, Position of patient used to obtain roentgenogram of inlet Note that the plane of the superior strait is parallel to the table top b, Roentgenogram of inlet obtained by using position indicated in a

has been shown[19, 21] that the plane of the superior strait is parallel to the table top when these conditions are satisfied

the nates so that it is in the midsagittal plane of the body (Fig. 80, *a*). It is important that the film obtained (Fig. 80, *b*) show the images of the greater trochanters to overlie and that the sacrum, ischial spines and posterior border of the symphysis pubis be visualized easily. It is also important to have a clear shadow of the notched metal centimeter rule on the film.

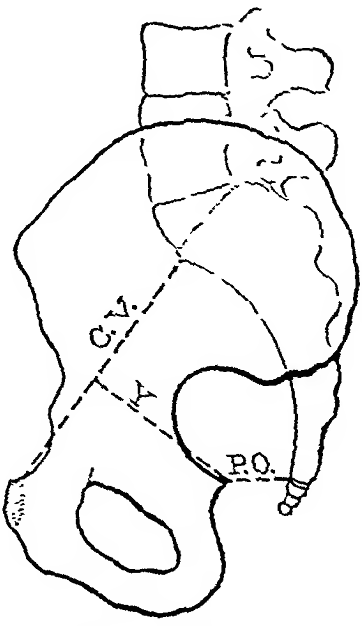


Fig. 82.—Lines to be drawn on and measurements to be obtained from lateral roentgenogram of the pelvis. *C.V.* represents the anteroposterior diameter of the inlet. *Y* represents the distance between the plane of the inlet and the plane of the ischial spines. *P.O.* represents the distance from the midpoint on a line joining the ischial spines to the tip of the sacrum.

Film of Subpubic Angle.—The patient lies supine upon the horizontal table. The tube is angled 33 degrees toward the head and centered just below the lower border of the symphysis pubis.[15] The technical factors are such as will produce a clear image of the subpubic arch (Fig. 81).

Mensuration.—*Lateral Film.*—Draw the following lines (Fig. 82):

(Fig. 79, *a*). The tube is centered about 5 cm. back (cephalad) of the symphysis pubis and the film is exposed. The factors vary according to the type of equipment available. It is important that the film obtained show (Fig. 79, *b*) clearly the promontory of the sacrum, the lateral walls of the pelvic inlet and the posterior border of the symphysis pubis. The pubes and ischia should overlie.

Fig 81.—Roentgenogram of subpubic arch obtained by using method described in text.

Lateral Film of the Pelvis.—The lateral film may be obtained by placing the patient on her side on the horizontal radiographic table, taking care that the *femoral trochanters* overlie each other. However, if a vertical *Bucky-Potter* diaphragm or a Lysholm grid is available is it preferable to employ the method described by Thoms and Wilson.[22] The patient removes her shoes and stands with either side to the target. The tube is centered just above the prominence of the greater femoral trochanter. The notched metal rule is placed between

on the anterior border of the first sacral vertebra. This may be the promontory or it may be at the point where the sacrum is cut by the ileopectineal lines. This line represents the anteroposterior diameter of the inlet, or the true conjugate.

(*b*) From the midpoint on a line joining the ischial spines drop a perpendicular to line *a*. This represents the distance from the plane of the ischial spines to the plane of the inlet.

(*c*) From the midpoint on a line joining the ischial spines draw a line to the tip of the sacrum. This serves as an estimate of the size of the posterior segment of the outlet.

Using calipers or a ruler, the distances represented by these lines may be measured on the image of the notched metal centimeter rule.

Film of Inlet.—Using the film ruler corresponding to the distance measured from the table top to the mark representing the spine of the fourth lumbar vertebra or from the table top to the upper border of the symphysis pubis, the following diameters are drawn and measured (Fig. 83): (*a*) greatest transverse and (*b*) anteroposterior of inlet.

Using the film ruler corresponding to the distance from the table top to the plane of the ischial spines (this distance is obtained by subtracting the distance between the plane of the ischial spines and the plane of the inlet as determined by means of the lateral view from the distance between the table top and the plane of the inlet), draw and measure the following diameter: (*c*) interspinous.

Film of Subpubic Arch.—Draw lines from the midpoint of the lower border of the symphysis pubis to the inner border of the ischial tuberosities and measure the angle formed (Fig. 84).

ANALYSIS

Architectural Types of Pelves.—From the film of the inlet the pelvis is classified according to the system of Caldwell and Moloy.[5, 10] They list five main groups, as follows:

1. *Anthropoid (dolichopellic type of Thoms).* The inlet is oval with the long axis running anteroposteriorly (Fig. 85).

2. *Gynecoid (mesatipellic and brachypellic types of*

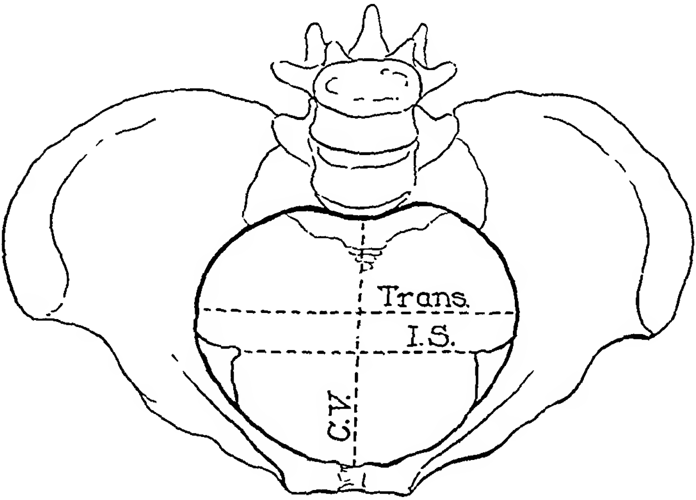


Fig. 83.—Lines to be drawn on and measurements to be obtained from the roentgenogram of the inlet. *Trans.* represents the greatest transverse diameter of the inlet. *C.V.* represents the anteroposterior diameter of the inlet. *I.S.* represents the interspinous diameter.

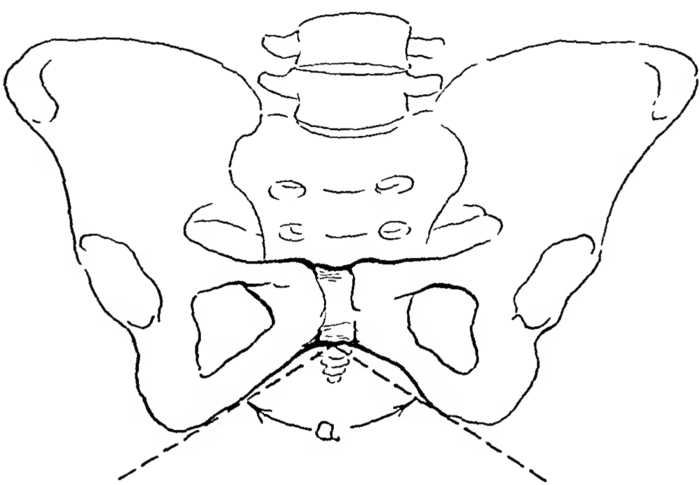


Fig. 84.—Lines to be drawn and angle to be measured on roentgenogram of subpubic arch.

(*a*) From the posterior border of the symphysis pubis about 1 cm. from its superior border draw a line to the closest point

greatest transverse diameter usually exceeds the anteroposterior by 2 cm. or more (Fig. 85).

4. *Android (not in Thoms' original classification).* The inlet is roughly triangular or blunt heart-shaped, with the apex of the triangle at the symphysis pubis (Fig. 85).

5. *Asymmetric.* The inlet, as the term implies, is not symmetric (Fig. 86).

In Caldwell and Moloy's classification subgroups exist, five of which are important, as follows:

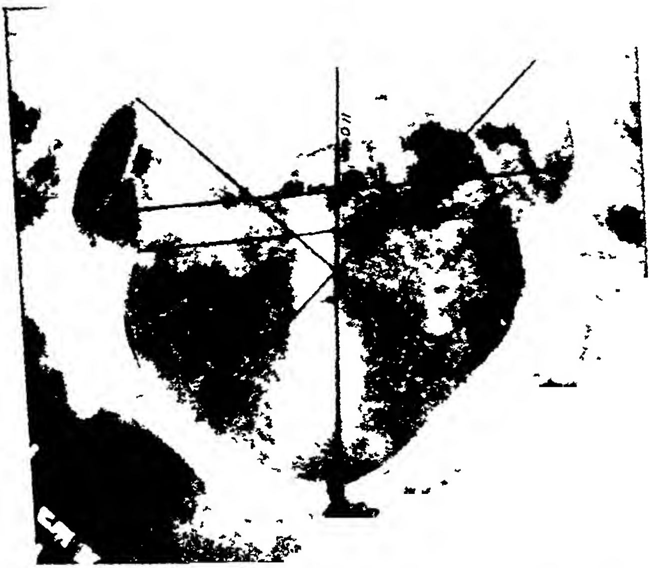


Fig 86—Roentgenogram of the inlet of an asymmetric pelvis.

1. *Anthropoid gynecoid.* The posterior half of the inlet is of the long oval type, but the anterior half is of the round type.

2. *Android anthropoid.* The inlet is roughly triangular, but the anteroposterior diameter exceeds the transverse.

3. *Android gynecoid.* The posterior half of the inlet belongs in the wedge-shaped group and the greatest transverse diameter is close to the sacrum, but the anterior half of the inlet is round and does not continue the triangular tendency of the posterior half. If the reverse is true, that is, round pos-

Thoms). The inlet is round. The transverse diameter does not exceed the anteroposterior in most instances by more than 2 cm. (Fig. 85).

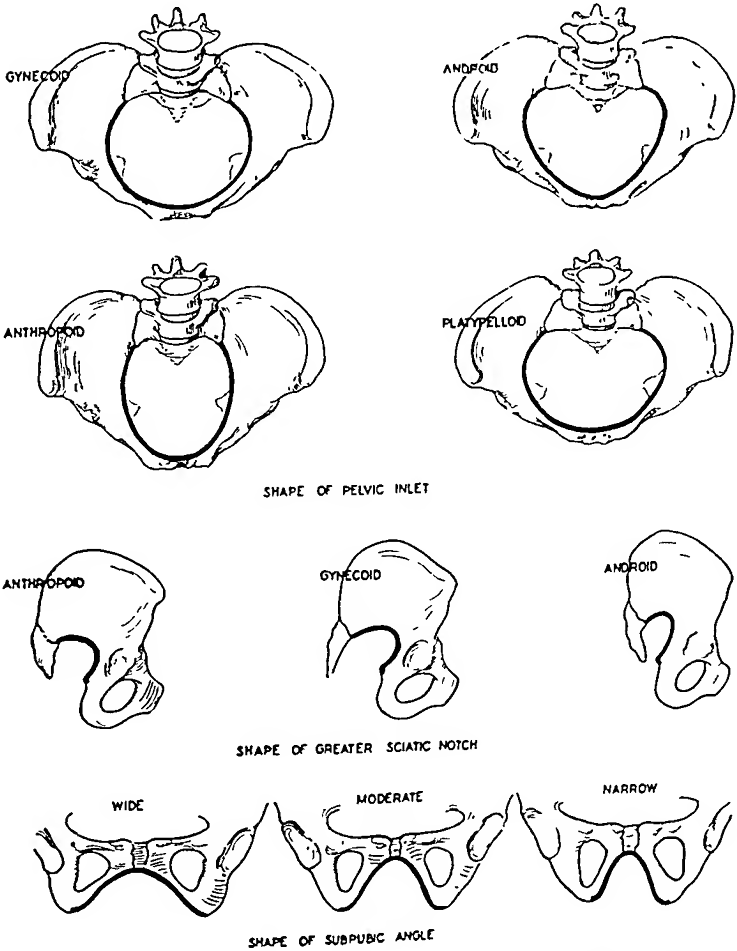


Fig. 85—Diagrammatic representation of the four main types of female pelvis according to the classification of Caldwell and Moloy (Reproduced from Garland, Pettit, Dunn and Shumaker, Radiology, 26: 446 [April] 1936)

3. *Platypelloid or flat (platypellic type of Thoms).* The inlet is oval with the long axis running transversely. The

greatest transverse diameter usually exceeds the anteroposterior by 2 cm. or more (Fig. 85).

4. *Android (not in Thoms' original classification).* The inlet is roughly triangular or blunt heart-shaped, with the apex of the triangle at the symphysis pubis (Fig. 85).

5. *Asymmetric.* The inlet, as the term implies, is not symmetric (Fig. 86).

In Caldwell and Moloy's classification subgroups exist, five of which are important, as follows:

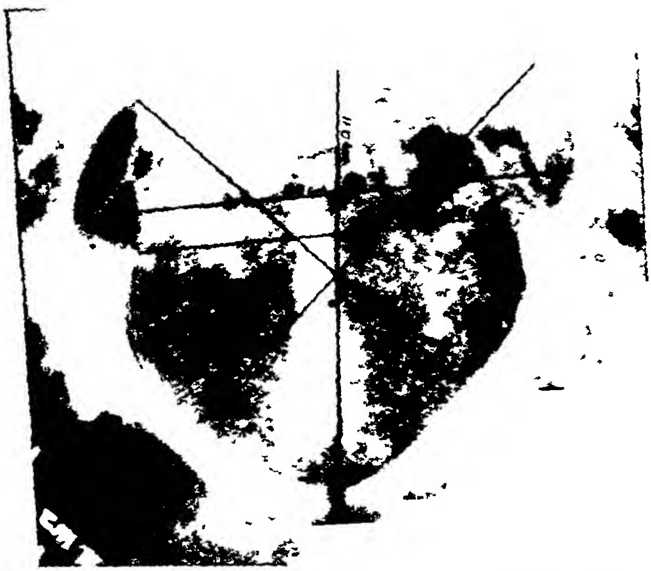


Fig. 86—Roentgenogram of the inlet of an asymmetric pelvis

1. *Anthropoid gynecoid.* The posterior half of the inlet is of the long oval type, but the anterior half is of the round type.

2. *Android anthropoid.* The inlet is roughly triangular, but the anteroposterior diameter exceeds the transverse.

3. *Android gynecoid.* The posterior half of the inlet belongs in the wedge-shaped group and the greatest transverse diameter is close to the sacrum, but the anterior half of the inlet is round and does not continue the triangular tendency of the posterior half. If the reverse is true, that is, round pos-

terior half and triangular anterior half, the inlet is rightly classified as gynecoid android.

4. *Android flat.* The inlet is wedge-shaped, but the transverse diameter exceeds the anteroposterior by more than 2 cm.

5. *Gynecoid flat.* The posterior half of the inlet is round but the anteroposterior dimension of the anterior half of the inlet is shortened.

Measurements.—The greatest transverse diameter divides the inlet into *anterior* and *posterior segments.* The latter determines the parent pelvic type, while the former indicates the subtype, if present. Where the posterior segment is small, the head must enter the birth canal mainly through the anterior segment and vice versa. The roentgenologist must point out such possibilities in his report.

Actual measurement of the inlet diameter is not as important as the general pelvic shape. It might be well to state, however, that an *anteroposterior diameter* of less than 10 cm. will usually cause inlet dystocia. In a like manner, a greatest *transverse diameter* which measures less than 11.5 cm. will cause trouble unless the anteroposterior diameter is long, as in the anthropoid type. In such a case the head may engage in the direct anterior or posterior position.

The *shape of the birth canal* depends upon the shape and inclination of the sacrum, the convergence or divergence of the side walls, and the depth of the pelvis. These factors are best determined from the lateral view and the film of the subpubic angle. Caldwell and Moloy[3, 4] have shown that the inclination of the sacrum depends upon the shape of the *greater sciatic notch.* They described three varieties, the narrow, the average, and the wide (Fig. 85), which usually accompany inlets belonging to the android, gynecoid and anthropoid groups respectively. This is not always the case, however, as a narrow notch may be found in the gynecoid and flat types, and a wide notch may occur in any type. The narrow notch throws the sacrum forward so that it encroaches upon the birth canal and shortens the posterior segment of the outlet. For this reason it offers the poorest prognosis. A wide notch, on the other

hand, inclines the sacrum backward, enlarges the posterior segment of the birth canal and outlet, and improves the chance of normal delivery.

Normally the sacrum describes a smooth curve with concavity directed anteriorly. If this curve is lacking or diminished the sacrum may encroach upon the midportion of the birth canal and cause midpelvic arrest. At the same time an exaggeration of this curve may cause the tip of the sacrum to lie more anterior than usual and shorten the posterior segment of the outlet.

All these abnormalities are best seen on the lateral view. This view also offers a check upon the anteroposterior dimension of the inlet. Of the two determinations of this diameter this is probably the more accurate since the landmarks are more easily visualized and the chance for error in calculating the distance is lessened.

The *size of the posterior segment of the outlet* is indicated on the lateral film by the line joining the tip of the sacrum and the ischial spines. This line does not lie in the plane of the outlet, but experience has shown that its length becomes shorter as the anteroposterior diameter of the outlet decreases. Since the ischial spines can be located much more accurately than the ischial tuberosities which are actually included in the formation of the outlet, it is felt that use of the spines in measurement of the outlet offers less opportunity for error.

In like manner, the *interspinous diameter* is more accurately measured on the roentgenograms than the intertuberous diameter. The interspinous diameter is, of course, the narrowest transverse diameter of the midpelvis, but it also offers a clue to the transverse diameter of the outlet. One measures the interspinous diameter by employing the film ruler which was obtained at the height from the table top corresponding to the height of the plane of the spines from the table. Since the height of the plane of the inlet is known, the distance from the spines to the plane of the inlet is obtained from the lateral film and subtracted from this value. This gives the distance from the plane of the spines to the table top (see diagram in

Fig. 87). Indication of possible trouble in the midpelvis or outlet is found in interspinous measurements of less than 10 cm. or in distances of less than 3 cm. from the tip of the sacrum to the ischial spines.

The *subpubic arch* varies from narrow to wide (Fig. 85). It is of little importance as long as the posterior segment of

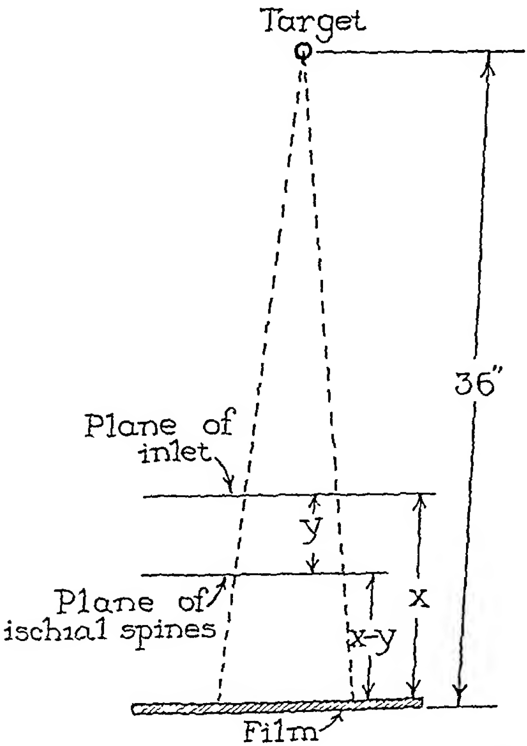


Fig 87.—Method of obtaining distance from plane of ischial spines to table top X is known, Y is measured on lateral roentgenogram of pelvis X minus Y equals distance

the outlet is large enough to permit passage of the fetal head. Whenever there is shortening of the posterior segment of the outlet or narrowing of the transverse diameter of the outlet a wide subpubic arch may offer compensation. In classifying the arches as wide, average or narrow, it is well to measure the angle formed. Garland[13] has commented upon the difficulty of

judging the arch without actual measurement. The average angle formed by the arch is between 90 and 100 degrees. Less than 90 degrees is considered narrow and more than 100 degrees wide.

The convergence or divergence of the lateral walls of the birth canal is noted best on the film of the subpubic arch. The information gained is valuable in formulating an opinion as to the shape of the "tunnel" of the birth canal.

COMMENT

Relative Incidence of Pelvic Types.—The relative incidence of the various pelvic types has been reported by many authors.[3, 10, 13, 14, 20, 25] Although there is a certain amount of agreement in all reports, the incidence varies somewhat according to the class of patients from which the material is drawn. Greulich and Thoms[15] found that the long oval or anthropoid type of inlet was more frequent in a series of 100 nurses and 107 children than in a corresponding series of 582 patients of a clinic. This Thoms attributed to the fact that the latter group represents a somewhat lower economic stratum of society than the former. He postulated that "adequate nutrition during early life and other factors which make for the attainment of maximum normal body size prevent that degree of anteroposterior flattening of the pelvis which has come to be considered as characteristically feminine."[20]

In Table 1 the relative incidence of the various types of female pelvis as given by several authors is shown. Cases with mixed tendencies are grouped with the predominant or parent type.

Prognosis of the Course of Labor.—In general, the prognosis as to the course and outcome of labor varies with the different pelvic types. It should be emphasized, however, that the individual pelvis may vary in such a way as to overcome the favorable or unfavorable factors present in the parent type. General contraction may be found in a pelvis of any type. The same is true of contraction of the outlet, straightening of the sacrum, and other conditions which alter the course of labor.

In the individual case, it is not enough for the roentgenologist to classify the pelvis; he should also note the significant variations in architecture.

The classic *gynecoid* pelvis offers a good prognosis. Delivery usually takes place spontaneously. In most cases

TABLE 1

PERCENTAGE DISTRIBUTION OF DIFFERENT TYPES OF FEMALE PELVES

	Type of Pelvis				
	Gynecoid	Anthropoid	Android	Platypelloid	Asymmetric
Author's series of 212 patients ..	52	20	18	8	1
Caldwell and Moloy; 215 unselected primigravidas (1934)	58	18	22	1	
Moloy and Swenson (1936).	51	26	19	4	
Garland; first series of 100 unselected primigravidas (1936)	53	21	21	5	
Garland; second series of 100 unselected primigravidas (1937)	51	18	21	10	
Walsh; 400 patients	56	17 25	23 75	3	
Thoms; 582 clinic women	78 8*	14 5	*	6 7	
Thoms; 100 nurses	63*	37	*		

* Android type not recognized by Thoms. These patients are included in gynecoid group.

engagement takes place in the transverse position and the head delivers with the occiput anteriorly.[10]

Anthropoid configuration offers a prognosis almost as good as that found in the gynecoid group. The head more frequently engages with the long axis in the sagittal plane and for that reason more occiput posterior and other abnormal pres-

entations are encountered. If transverse arrest is encountered, traction with forceps should not be attempted until the head is rotated to the anteroposterior diameter.[8, 10]

Because of the shape of the inlet in *flat* pelves, there may be failure of engagement. Engagement most often takes place in the transverse position and this position should be maintained to a low level in cases in which forceps delivery is attempted.[8, 10] The flat pelvis offers a much poorer prognosis than do pelves in either the anthropoid or gynecoid class.

The poorest pelvis from the standpoint of normal delivery is the *android,* the type showing masculine characteristics. Because of its heart-shaped or triangular inlet, engagement takes place less readily. In addition, most pelves belonging to this class show some degree of contraction of the outlet. Long, difficult labor is the rule rather than the exception and operative delivery is necessary more frequently. Injury to the baby is more common in this group than in any of the others. It should be noted here that the obstetrician finds it more difficult to recognize this type of pelvis than any other by means of the clinical examination and the obstetric measurements.

Many factors influence the course of labor in addition to variations in pelvic architecture. Dystocia may be caused by enlargement of the fetal head, by large soft parts in the maternal pelvis, or by weak uterine contractions. These are but a few of the things which the obstetrician must consider. The aid given by the roentgenologist is often of inestimable value but it is not the "last word." Roentgenologic pelvimetry serves its purpose only in so far as there is understanding and co-operation between the roentgenologist and the obstetrician. With this fact in mind, the wise roentgenologist gives the obstetrician a description of the shape of the tunnel of the birth canal, he calls attention to significant changes in pelvic architecture, he points out where and why dystocia may occur, but he suggests such radical procedures as cesarean section only when he feels certain in his own mind that pelvic configuration precludes the possibility of delivering a living baby.

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ROENTGENOGRAPHY IN THE DIAGNOSIS OF TUMORS OF BONE

CHARLES G. SUTHERLAND

The principle concern in the diagnosis of tumors of bone is a definite decision as to whether the abnormal growth is benign or malignant. In the making of such a decision roentgenography holds a key position.

VALUE OF THE ROENTGENOGRAPHIC PROCEDURE

Given adequate technic, the roentgenogram contains as much evidence of the nature of any lesion to which roentgen study is applicable as does the cut section of tissue made and prepared for microscopic study, and in some cases the roentgenogram contains more evidence than the cut tissue. When a correct diagnosis cannot be made by the roentgenographic method, therefore, the roentgenogram or the roentgenographic method should not be blamed. In almost all cases, failure must be attributed to lack of knowledge and experience on the part of some diagnosticians, and carelessness in the use of knowledge and experience on the part of others.

The roentgenographic image affords a reproduction in relief of all the structures of the body of sufficient density to offer resistance to the passage of what was termed by its discoverer, "the *x*-ray." Tissues which are in themselves ordinarily nonresistant to the passage of roentgen rays may, because of their bulk, cast a shadow of varying intensity in the roentgenogram.

The making of a roentgenographic diagnosis is accomplished by interpretation of the significance of changes in the *contour* and in the *density* of the tissues concerned. Although

plasm"; this is described as "a new growth atypical in structure and termination."

For practical purposes, tumors may be divided into two groups: the *benign* abnormal growth which offers no menace to the life expectancy of the individual concerned and the *malignant* abnormal growth which, if not adequately treated or otherwise dealt with, will terminate the life of the afflicted one within a comparatively short time.

Benign Tumors of Bone.—Benign tumors may be subdivided into two groups: the benign *osteogenic* abnormal growth, which evidently has its origin in a congenital defect of the periosteum, and a group of tumors which have their origin in some *aberration of normal reparative processes.* In the latter are placed giant cell tumor and osteodystrophia fibrosa cystica with cysts in bone. "Osteodystrophia" signifies defective formation of bone and more nearly accurately describes the pathologic findings in this type of bone lesion than the generally used term "osteitis fibrosa cystica." Strictly speaking, the lesion is not an inflammatory one.

There are noninflammatory lesions which in some cases involve the periosteum and which in others occur in the contiguous soft tissue structures. These lesions may simulate benign osteogenic tumors or they may have to be distinguished from some types of malignant tumors which involve bone. These have been classified as "traumatic osteomas" and are the results of ossification in soft tissue structures following trauma. The unruptured subperiosteal hematoma has some of the roentgenographic characteristics of the benign osteogenic tumor, whereas the ruptured subperiosteal hematoma permeates the adjacent soft tissue structures and casts a series of shadows which may be misinterpreted as being one form of malignant osteogenic tumor.

Differential Diagnosis of Benign and Malignant Forms of Tumor.—The pathognomonic feature of the benign tumor which involves bone is *retention of the continuity of the contour* of the bone throughout. The generally accepted normal contour of the bone may be expanded or otherwise dis-

this would appear to be a comparatively simple affair, it has not proved to be such in practical experience.

REQUISITES OF SUCCESSFUL ROENTGENOGRAPHY

There is a marked analogy between the recognition of the nature of tumors involving bone and the soft tissue structures of the various parts of the body and the recognition of human beings by the fingerprint method. Success in either of these is based on *a wide acquaintance with inherent characteristics* which follow a constant pattern. This wide acquaintance can be obtained only by careful study and frequent review of large series of examples, and because of this the accuracy of any given opinion always will have to be gauged by the knowledge and experience of the individual interpreter.

Neoplasms have the same habits and affinities for specific habitat that human beings have. These can be elicited in the taking of the history of a patient afflicted by a tumor in bone. A primary roentgenographic examination of all such patients provides the fingerprint and the *correlation of the roentgenographic finding with the factual data* of the clinical history and other laboratory findings assists in the final decision of the true nature of the tumor.

Although the roentgenographic diagnosis may be accurate in a considerable number of cases, no radical procedures should ever be carried out without this correlation of all other findings. In cases of doubt, biopsy should be done and the opinion of a competent pathologist should be obtained before any surgical procedures inimical to the future usefulness of the part involved are undertaken.

Experience has taught that there are certain fundamental principles that can assist materially in the proper interpretation of the roentgenographic findings in cases of tumor of bone.

TYPES OF TUMORS OF BONE; FUNDAMENTAL ROENTGENOGRAPHIC CHARACTERISTICS

Tumor is defined as "an abnormal mass of tissue, not inflammatory, arising without apparent cause from cells of preexistent tissue and having no physiologic function." An analogous term sometimes used to signify a tumor is "neo-

The pathognomonic feature of the malignant osteogenic form of tumor is *dissolution of the contour shadow* of the bone (Fig. 89, *a*). In the majority of cases the malignant osteogenic tumor will invade the contiguous soft tissue structures and when it does it is impossible to trace the outline of the tumor; it either "promiscuously" invades the normal shadow of the structures or fades imperceptibly into the surrounding normal shadow (Fig. 89, *b*).

Fig. 89.—*a*, Malignant osteogenic tumor: dissolution of the cortical contour sharply demarcates normal from involved portions of bone; *b*, malignant osteogenic tumor, showing "promiscuous" *invasion of the contiguous soft tissue.*

When the tumor involves a flat bone, such as one of the innominate bones or the skull, the defect in the shadow of the bone is *smooth margined* and well defined in the case of the benign tumor (Fig. 90, *a*), whereas in the case of the malignant tumor the defect has an *irregular* or sometimes *serrated outline*, or the outline may not be discernible: it may fade imperceptibly into the shadow of the surrounding normal bone (Fig. 90, *b*).

torted, but its continuity is never broken (Fig. 88, *a*). Certain benign forms of tumor will distend the cortex and invade the contiguous soft tissue structures. When this occurs, careful

Fig. 88.—*a*, Benign osteogenic tumor: the continuity of the cortical contour is maintained throughout; *b*, the shadow of the invading benign osteogenic tumor is demarcated throughout.

study of the soft tissue structures (with the roentgenogram held in front of a concentrated light if necessary) will reveal that the contour of the invasion shadow is intact throughout (Fig. 88, *b*).

These points in differential diagnosis hold true to a surprisingly high degree in the case of both osteogenic benign tumors and osteogenic malignant tumors. Three striking exceptions to this rule must be kept in mind. *Tumors of soft tissue* and *periosseous fibrosarcoma* may involve bone by pressure erosion. In the majority of such cases the defect in the bone may be smooth margined, although not so well defined as in the case of the benign osteogenic tumor. *Ewing's endothelioma* (Fig. 91, *a*) usually commences as a subperiosteal lesion and may expand the cortex and distort it without breaking through and invading the contiguous soft tissues. When it does invade them, the outline of the invasion shadow is hazy and poorly defined: it is not so definitely demarcated as the outline of the benign osteogenic tumor, nor is it so "promiscuously" distributed as the outline of the malignant osteogenic tumor. *Myeloma*, on the other hand, violates all the rules that can be laid down for the roentgenologic differentiation of the benign and malignant forms of tumor. In the long bones of the extremities (Fig. 91, *b*), and in the ribs and the clavicle, myeloma will expand and distort the contour of the bone to a marked degree without any dissolution of the continuity of the cortical outline. The translucent shadow of the region affected by the tumor may be transversed by numerous trabeculae of bone, such as are frequently observed in the presence of giant cell tumor. But the trabeculations are coarser and more widely spaced than are those of giant cell tumor. There may be no expansion of the cortex, but there may be numerous small defects distributed throughout the shadow of the bone (Fig. 92, *a*), each as smooth margined and discrete as if made with a steel punch. These small vacuolated regions are best seen in the vertex of the skull; where there is doubt as to the nature of the lesion involving other bones, roentgenologic examination of the patient's head should be made to corroborate or to eliminate myeloma as the etiologic factor.

Malignant Tumors of Bone.—Roentgenographically, malignant tumors of bone are divided into three groups: the

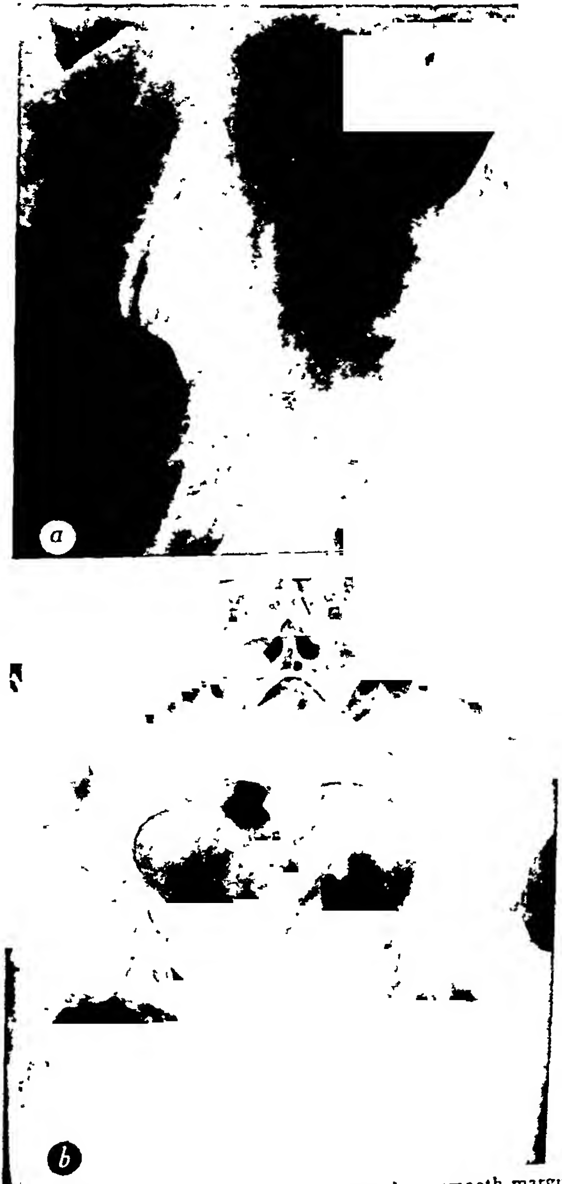

Fig. 90.—*a*, Benign osteogenic tumor there is a smooth-margined and sharply defined filling defect in the bone; *b*, malignant osteogenic tumor in which the filling defect fades imperceptibly into that of the surrounding portions of normal bone.

Fig. 92.—a, Myeloma involving the skull, with discrete filling defects in the shadow of the bone easily demonstrable; b, osteolytic or osteoclastic type of metastatic malignant involvement of bone in the pelvic region, showing the typical "melted ice" appearance of the diffuse destruction of bone. This malignant process often is secondary to carcinoma of the breast, kidney, thyroid gland and lung.

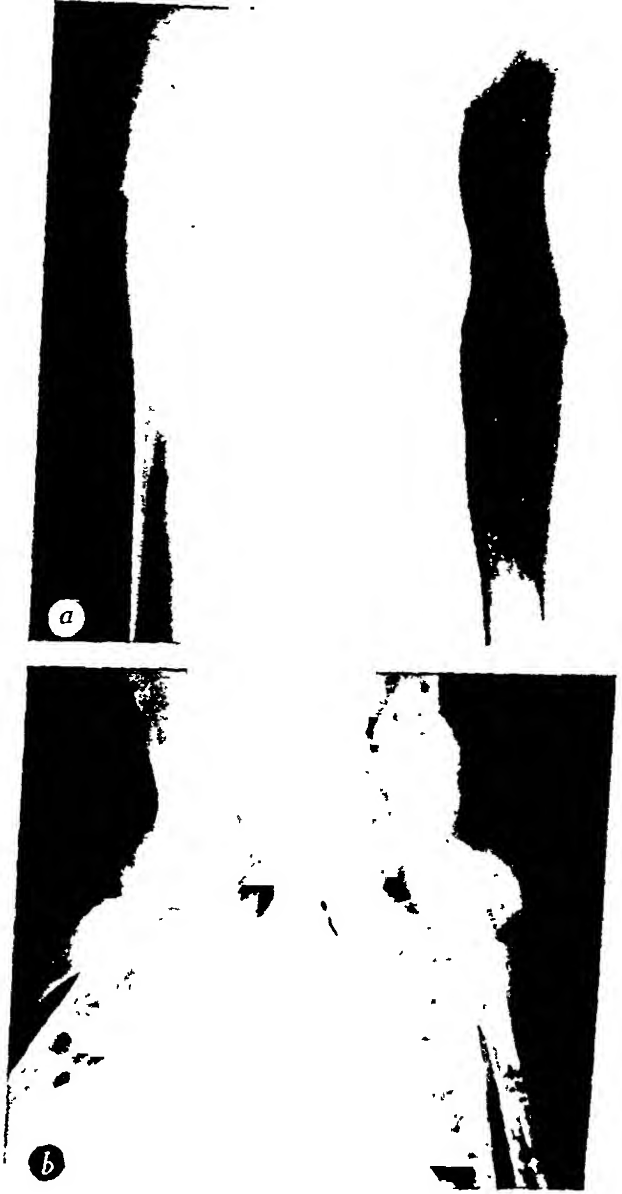

Fig. 91.—*a*, Nonosteogenic malignant tumor of bone (Ewing's endothelioma) in which elevation of the periosteum in a laminated manner and rather indistinct demarcation of the shadow of the invading tumor are apparent in the region of soft tissues; *b*, myeloma of long bones of extremities, characterized by smooth-margined discrete filling defects in the bone shadow and expansion of the cortical contour without dissolution of the continuity of the cortical contour.

Fig 92—a, Myeloma involving the skull, with discrete filling defects in the shadow of the bone easily demonstrable; b, osteolytic or osteoclastic type of metastatic malignant involvement of bone in the pelvic region, showing the typical "melted ice" appearance of the diffuse destruction of bone. This malignant process often is secondary to carcinoma of the breast, kidney, thyroid gland and lung

malignant osteogenic tumor, the malignant nonosteogenic tumor and the malignant metastatic (secondary) tumor.

Metastatic Malignant Involvement.—Malignant metastatic tumors which involve bone result from the deposition of an embolus or the emboli of cells detached from tumors in parts of the body distant from bone, carried by the blood stream, or by the lymph to a point at which they enter the blood stream; they are carried and deposited at a site at which conditions are favorable to their development and growth. The cells in the metastatic tumor have all the characteristics of those of the primary tumor. Sometimes, discovery during roentgenologic examination of a metastatic malignant process which involves bone may be the first evidence of the presence of such a lesion, and by biopsy of the metastatic tumor the nature of the primary tumor can be determined when other methods have failed to determine it.

Carcinoma metastasizes in bone, and the higher the grade of the malignancy, the more frequently does metastasis occur. Lesions identical in their roentgenographic images are seen in cases of osteogenic sarcoma. These are not generally accepted as being metastatic, but are regarded as multiple involvement by primary osteogenic tumors. Involvement of bone is seen in cases of *malignant lymphoma* (Hodgkin's disease, lymphosarcoma and leukemia) and occasionally in cases of *Ewing's endothelioma.*

Two distinct types of roentgenographic image are seen in metastatic malignant involvement of bone. The *osteolytic* or *osteoclastic type* (Fig. 92, *b*) is exemplified in a diffuse destruction of the bone which is best described as a "melted ice" appearance, in which the shadow of the bone in one section is completely lost, or as a "melting ice" appearance, in which, if the normal bone structure is thought of as being composed of ice, the destruction resembles very much the honeycombing that occurs when a block of ice is exposed to a temperature at which slow melting would occur. The *osteoplastic* or *osteoblastic* (proliferative) *type of tumor* (Fig. 93, *a*) exhibits varying degrees of sclerosis superimposed on and occurring

concomitant with osteolysis. Evidence of the trabeculae observed in normal bone shadows is completely lost and the bone

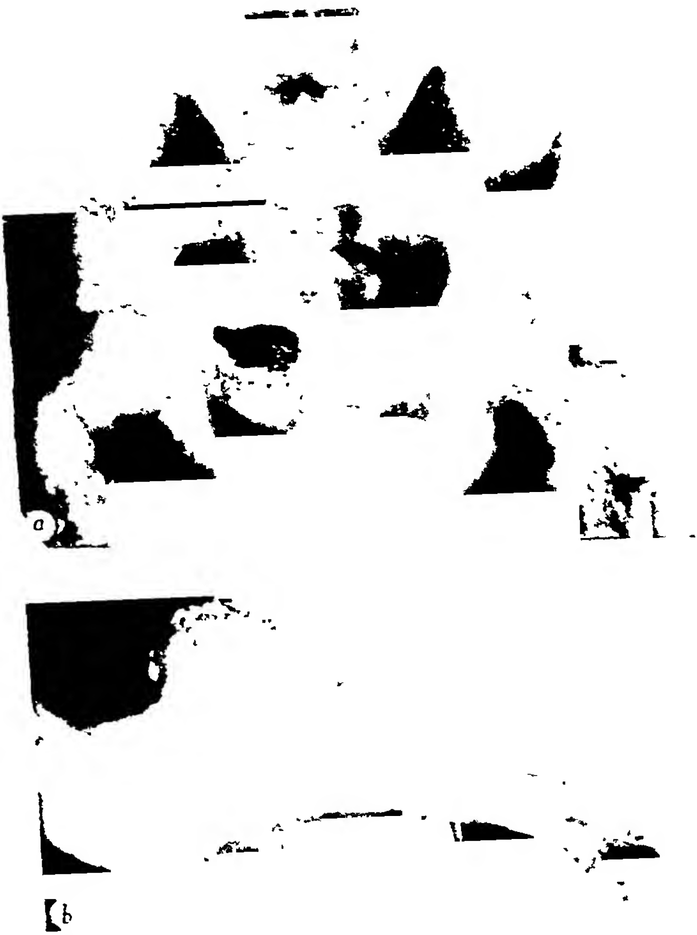

Fig. 93.—*a*, Osteoplastic (proliferative) type of metastatic malignant lesions of bone, in the pelvic region, showing coincidental occurrence of destruction of bone and osteodystrophia (defective formation of bone): this lesion most frequently is secondary to carcinoma of the prostate gland; *b*, chondroma, a cartilaginous benign osteogenic tumor of which the shadow is demarcated throughout.

shadow is replaced by that of a coarsely granular, greatly increased density. The most valid explanation of this bony

change is that some pressure (probably that exerted by enlarged glands) has affected the vessels supplying arterial blood to the affected part, with a gradual diminution of the blood supply and a resultant resorption of calcium by the damaged cells, with formation of osteoid tissue. This hypothesis is strengthened by the fact that the osteoplastic form occurs predominantly with carcinoma of the prostate gland, which is a comparatively slow growing tumor, as the primary neoplasm. On rare occasions, a tendency toward the occurrence of the osteoplastic type of lesion is noted in cases of carcinoma of the stomach and carcinoma of the breast. Investigation of these osteoplastic lesions proves them to be secondary to slowly growing scirrhous carcinomas.

FURTHER OBSERVATIONS THAT SIMPLIFY THE CLASSIFICATION AND POINT TO THE TYPE OF TREATMENT

The fundamental principles by which the various forms of tumors of bone may be recognized and properly classified have been stressed to this point with a view of outlining primarily the knowledge that is absolutely necessary to the roentgenographic diagnosis of such lesions.

With increasing knowledge and experience, the various groups can be further subdivided. From the practical point of view this is not necessary, but by correlation of roentgenographic findings some interesting observations can be made that add to simplification of the classification of lesions of bone in general and aid in the determination of therapeutic measures best suited in the individual case.

Benign Osteogenic Tumors.—A study of a large group of benign osteogenic tumors shows that the majority occur among young persons during the period of growth of bone. Such tumors have a specificity of location; nearly all occur in the metaphysis of the bone, which is the growth area immediately adjacent to the epiphysis. The tumors tend to increase in incidence up to the age at which maturity of bone growth is attained, and growth in the tumor stops at this period. There

may even be a diminution in the volume of the tumor mass following this period.

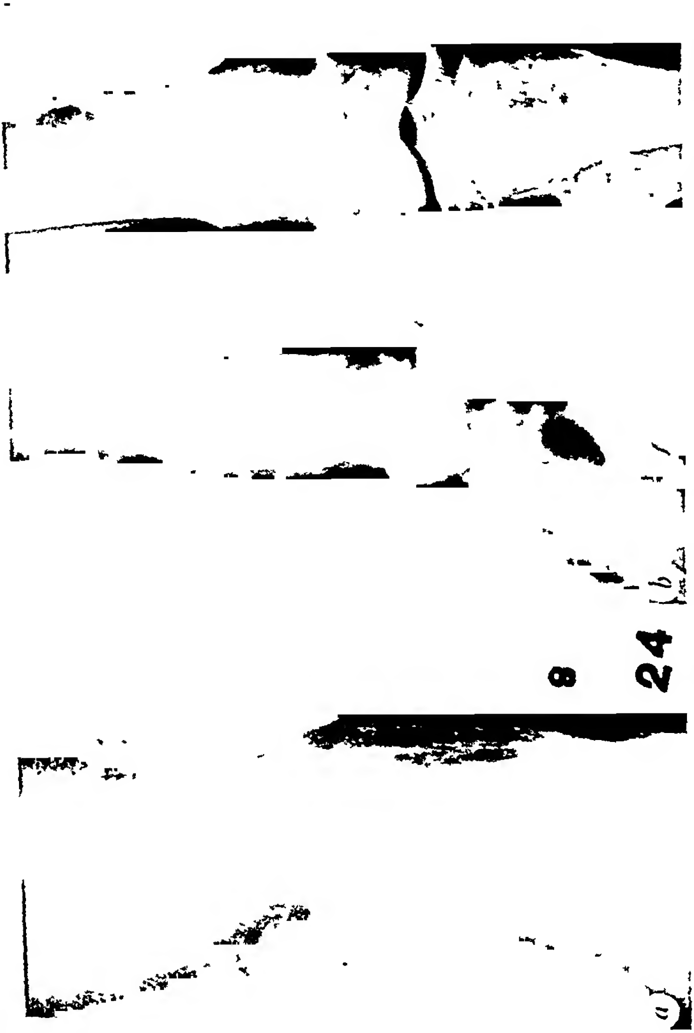

Fig 94.—*a*, Exostosis, a type of benign osteogenic tumor; *b*, multiple congenital exostoses (hereditary chondrodysplasia) Both conditions are identical in origin, and both probably are caused by a congenital defect in the periosteum which controls the architecture of bone.

The tumor may commence at the metaphysis and be carried by the growth in the length of the bone into the diaphysis or shaft. Such a tumor is cartilaginous, and therefore can

properly be classed as a *chondroma* (Fig. 93, *b*). When multiple chondromas occur in the same patient, the lesion is frequently taken out of the classification of tumors, and becomes the object of many hypotheses and is given a widely variant nomenclature. Thus, *exostosis* (Fig. 94, *a*) is a "chondroma," an "osteochondroma," an "osteoma" or various combinations of the same names. When multiple occurrences are present the condition (Fig. 94, *b*) is referred to as "diaphyseal" or "metaphyseal aclasis," "chondrodysplasia" or "hereditary deforming exostoses" and is classified as chondrodystrophy. Among the hypotheses offered as to the cause of this lesion is found the suggestion that the cause is a congenital defect in the periosteum through which normal control of the bone architecture is altered to a greater or lesser extent, so that abnormalities of growth occur. This seems to be the simplest and most practical explanation of the etiology of the condition and seems applicable to the whole group of benign osteogenic tumors.

In the same patient a large osteochondroma of the radius was observed with typical multiple exostoses symmetrically distributed throughout the majority of the metaphyseal portions of the long bones of both extremities. A similar phenomenon was observed of other patients who had symmetrically distributed typical exostoses and massive osteochondroma in the ribs, the scapula or other isolated parts. Multiple occurrence of chondroma was noted of other patients. This particular type of lesion also has been taken from the tumor group and has been described as "chondrodysplasia" or "cartilaginous dystrophy." For practical purposes it would seem that all the conditions previously mentioned properly could be placed in the category of "benign osteogenic tumors" and efficiently described as "chondromas," which they all are.

A confusion similar to that of roentgenologic nomenclature of the lesions under consideration has long existed in pathologic nomenclature because an attempt has been made to *describe* every shred of tissue found in the individual tumor. If the hypothesis is accepted that benign osteogenic tumors arise as results of congenital defects in the periosteum and are results

of a partial loss of the normal inhibitory control over growth, then such tumors are all *chondromas* (Fig. 95, *a*). Alteration in the rate of growth of one type of cell might make a given tumor a *fibroma*, a *chondroma*, an *osteoma* (Fig. 95, *b*) or any combination of these terms that the individual observer might

Fig. 95.—*a*, Chondroma; *b*, osteoma of the ilium. Alteration in the rate of growth of one particular type of cell might make such tumors fibromas, chondromas, osteomas, or any combination of descriptive terms which an observer might wish to employ.

wish to employ. Mucinous changes in the tumor would add the term "myxo-" to the single or the combined appellation. All I wish to do herein is to point out the fact that from the standpoint of diagnosis and subsequent therapeutic measures, a thoroughly adequate and proper diagnosis of any of the con-

properly be classed as a *chondroma* (Fig. 93, B). When multiple chondromas occur in the same patient, the lesion is frequently taken out of the classification of tumors, and becomes the object of many hypotheses and is given a widely variant nomenclature. Thus, *exostosis* (Fig. 94, *a*) is a "chondroma," an "osteochondroma," an "osteoma" or various combinations of the same names. When multiple occurrences are present the condition (Fig. 94, *b*) is referred to as "diaphyseal" or "metaphyseal aclasis," "chondrodysplasia" or "hereditary deforming exostoses" and is classified as chondrodystrophy. Among the hypotheses offered as to the cause of this lesion is found the suggestion that the cause is a congenital defect in the periosteum through which normal control of the bone architecture is altered to a greater or lesser extent, so that abnormalities of growth occur. This seems to be the simplest and most practical explanation of the etiology of the condition and seems applicable to the whole group of benign osteogenic tumors.

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tion of normal reparation of the bone. The tumor commences apparently under the periosteum and seems to have a pre-

Fig 96 —*a*, Giant cell tumor, a benign granuloma involving bone, in the early stages; *b*, giant cell tumor: expansion of the tumor obliterates the trabeculae and the cortical contour; the wavy remnant of bone tissue and the continuity of the shadow of the tumor denote a benign tumor.

dilection for the epiphysis in contradistinction to the majority of other tumors of bone, which have their origin in the metaphyseal portion of the bone. The tumor expands centripetally,

ditions mentioned herein would be "benign osteogenic tumor" or, if it be wished, "chondroma."

The perfectly obvious fact that I have attempted to establish is that any therapeutic measures employed for the tumors under consideration must be *conservative.* Until after maturity of growth has been attained, at least, correct therapeutic procedure would seem to be not to disturb these tumors. This contention has been borne out in cases in which, because the tumors had attained such a size or were in such a position that mechanical interference with function had occurred, an attempt was made to remove them. Excepting in those cases in which it has been possible to remove every vestige of cartilage or to destroy it, these tumors in general have shown a tendency to recur and in recurring have grown very rapidly and have attained huge dimensions. In a proportion of cases of recurrence, an apparent mutation of the cells has occurred, resulting in an osteochondrosarcoma which proved rapidly fatal to the patient.

Because of the nature of the benign osteogenic tumor, it shows no definite favorable reaction to radiotherapy.

Benign Nonosteogenic Tumors.—Benign nonosteogenic tumors which involve bone are comparatively rare. *Hemangioma* may occur in the long bones; it is more frequently seen in the vertebral bodies. In long bones it tends to occur just under the periosteum and expands centrifugally. The result is expansion and distortion of the cortex of the bone, which has been very appropriately described roentgenographically as a "soap bubble effect." In the vertebral bodies osteolysis of the bone and accentuation of the trabecular elements of the bone occur, producing a striated appearance which runs vertically across the translucent shadow of the bone. Pathologic fracture occurs rather frequently in hemangioma of the vertebral bodies.

Giant cell tumor may be classed as a "benign granuloma involving bone." The hypothesis as to causation is that, following trauma, hemorrhage into the bone occurs. Continued function causes secondary hemorrhage which results in aberra-

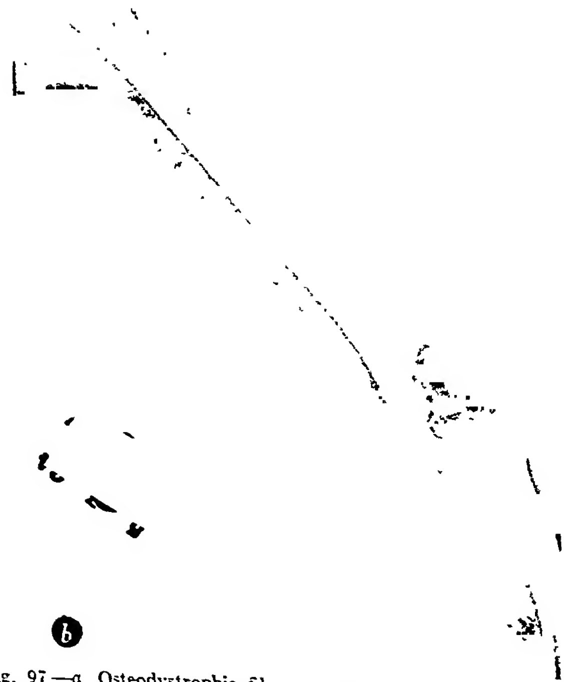

Fig. 97.—*a*, Osteodystrophia fibrosa cystica (localized) is an anomaly of
the normal reparative process similar in causation to giant cell tumor; *b*, the
same condition. The tumor commences at the metaphyseal border and may
be carried by growth of the bone into the shaft.

crossing the bone and expanding the cortex on the opposite side. In the early stages (Fig. 96, *a*) the bone shadow exhibits a translucent density with a network of bony trabeculae superimposed. As the tumor expands, the trabeculations are lost and the shadow of the bone becomes one of a homogeneous "ground-glass" appearance. With expansion of the cortex the tumor invades the adjacent soft tissue structures (Fig. 96, *b*), and the line indicating the cortex may be thinned to the point at which it becomes imperceptible. At this stage the tumor may be difficult to distinguish from a malignant osteogenic tumor. Observation of the soft tissue region with the roentgenogram held in front of a concentrated light will show the contour of the shadow to be intact and will establish the benign character of the tumor.

Giant cell tumors respond favorably to radiotherapy. At first the roentgenogram may show an apparent increase in size and clinically the results may be discouraging but after a short period a definite regeneration of the bone occurs and continues.

Osteodystrophia fibrosa cystica (Fig. 97, *a*) and *simple* or *hemorrhagic cysts* in bone (Fig. 97, *b*) have a causation similar to that of the giant cell tumor. The lesion begins at the metaphyseal border of the long bone. Many of such lesions apparently have existed for years and have been carried by growth in length of the bone into the diaphysis. It is noteworthy, in this respect, that generalized osteodystrophia fibrosa cystica is indicative of tumor of the parathyroid glands with an alteration in calcium metabolism; the bone porosis must be generalized. Localized osteodystrophia, on the other hand, is never significant of tumor of the parathyroid glands.

Apparently, because of its chronicity, osteodystrophia fibrosa cystica does not respond so favorably to radiotherapy as do other conditions mentioned. In single cysts involving bone, destruction of bone may be so extensive at one point as to cause pathologic fracture. To obviate this (or in treatment subsequent to such a fracture), it may be necessary to resect a portion of the shaft of the bone and to insert a transplant of bone.

tral or *medullary type*, (2) the *periosteal type*, with the "sun-ray" effect of bony spicules radiating at right angles or nearly right angles to the shaft of the bone, (3) the *sclerosing type* with its dense eburnation of the metaphyseal portion of the shaft, (4) the *telangiectatic type*, with its diffuse infiltration of the soft tissues with bony spicules, producing a "small bush" effect in the roentgenogram and (5) the *chondrosarcoma* which, because of its preponderance of cartilage, may be very difficult to trace in its "promiscuous" invasion of the surrounding tissues. The majority of the lesions mentioned have their origin in the metaphyseal portion of the bone, in the growing portion, and usually extend toward the diaphysis. Rarely, an osteogenic sarcoma will extend into and involve the epiphysis. There is a form of osteogenic sarcoma that involves the mid-shaft and exhibits a series of waves of bony tissue widely distributed through the contiguous soft tissue structures. A similar extensive infiltration of the soft tissue structures is seen in the presence of some malignant angiomas. In response to radiotherapy, these tumors react less favorably than does Ewing's endothelioma, and yet a little more favorably than the osteogenic types of sarcoma.

Malignant Nonosteogenic Tumors.—*Ewing's endothelioma* is a tumor that has its origin subperiosteally and roentgenographically shows evidence of considerable irritation exemplified by a marked increased density of the bone and an elevation of the periosteum in successive layers which gives the cortex a laminated appearance (Fig. 98, *b*). This "onion-skin" appearance is considered rather pathognomonic of Ewing's endothelioma. Both the roentgenographic image and the clinical history of the patient affected frequently simulate very closely the roentgenographic image and clinical history in osteomyelitis (Fig. 99, *a*), and there may be difficulty in distinguishing these two lesions. A series of laminations of the cortex have been observed, with definite solution of the cortical continuity, and above this region a series of short spicules of bone radiate at right angles to the shaft of the bone. An interesting feature of Ewing's endothelioma is the fact that this

Malignant Osteogenic Tumors.—The term *"osteogenic"* in relation to malignant tumors involving bone does not necessarily imply the formation of bone in the tumor. This nomenclature was agreed on to designate a group of tumors that arose from bone cells or bone-forming cells, and to distinguish these

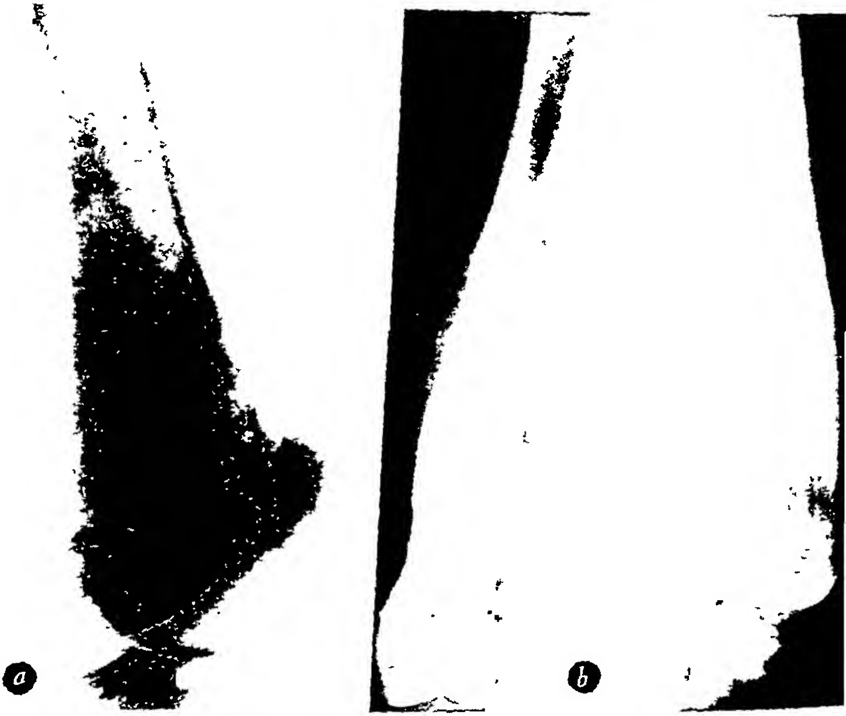

Fig. 98.—*a*, Malignant osteogenic tumor, characterized by dissolution of the cortical contour and "promiscuous" invasion of the contiguous soft tissues; *b*, nonosteogenic malignant tumor (Ewing's endothelioma), showing marked increased density of bone and elevation of the periosteum in successive layers which gives the cortex a laminated appearance.

from tumors which originate from bone marrow cells or the vessels of bone or marrow. The characteristic feature of this group, as before stated, is dissolution of the continuity of the contour (Fig. 98, *a*) of the bone as seen in the roentgenogram. The various types described in the older textbooks on pathology can be distinguished roentgenographically: (1) the *cen-*

elitis of Garré may suggest Ewing's endothelioma, but these conditions are all more definitely demarcated from the surrounding tissues than is Ewing's tumor. The ruptured subperiosteal hematoma exhibits coarse strands of bone tissue permeating the contiguous soft tissue structures, and the roentgenographic image which they cast is distinctive enough so that they should not be mistaken for Ewing's endothelioma.

Malignant angioma is comparatively rare. It exhibits a grotesque infiltration of the soft tissue structures with wavy strands of bone tissue distributed over a wide region. The reaction of this type of tumor to radiotherapy already has been described.

Malignant Metastatic Tumors.—*Differentiation of Carcinomatous Osteitis and Osteitis Deformans.*—The malignant metastatic tumors which involve bone have been described. An apparently benign type of osteitis similar to Paget's disease (probably a mono-osteitic type of osteitis deformans) is met with comparatively frequently involving a single *innominate bone.* This lesion may be difficult at times to distinguish. Metastasis from carcinoma of the *prostate gland* occurs in men of about the same age as those in whom osteitis deformans occurs. The evidence elicited at roentgenologic examination in some cases may be the first suggestion of the lesion in the prostate gland. In some cases, even after metastasis has been demonstrated, it is difficult to establish by physical examination the presence of carcinoma in the prostate gland. The course of carcinomatous osteitis and that of osteitis deformans often follow the same pattern. One innominate bone may be involved in carcinomatous osteitis before there is any evidence of involvement of other parts of the skeletal structure. The similarity of involvement of bone in these two types of lesions lends support to the hypothesis that the bone sclerosis is caused by some alteration in the arterial blood supply of the bone.

The pathologic process in osteitis deformans is subperiosteal deposition of an osteoid tissue. As a result of this, definite widening of the diameter of the bone occurs. This is apparent in the roentgenographic image of bone affected by

tumor reacts favorably to radiotherapy, and adequately treated patients who have the tumor will obtain marked regeneration of bone in the affected region (Fig. 99, *b*), with formation of

Fig. 99.—*a*, Nonosteogenic malignant tumor (Ewing's endothelioma) of the femur, a condition which frequently simulates osteomyelitis, both in the roentgenographic image and the patient's history; *b*, marked regeneration of bone and formation of a firm periosteal shell (involucrum) in Ewing's endothelioma after adequate radiotherapy.

a thick outer shell of bone very similar to that seen in cases of chronic osteomyelitis.

The intact form of *subperiosteal hematoma* and the *chronic sclerosing osteitis* which follow trauma or the localized infective osteitis sometimes spoken of as *nonsuppurating osteomy-*

osteitis deformans. There is an exaggeration of the trabecular elements in the shadow cast by the bone.

In carcinomatous osteitis, primary osteolysis occurs in which evidence of the trabecular elements of the bone is obliterated. Resorption of the calcium produces osteosclerosis, which results in a coarsely granular deepening of the density of the bone. There is no apparent enlargement of the shadow of the bone.

These differential points in carcinomatous osteitis and osteitis deformans are best brought out in a roentgenogram which shows the bones of the pelvis and the upper half of the femoral shafts. In osteitis deformans a decided widening of the cortical region and a bowing of the shaft of the bone will be seen (Fig. 100, *a*). In carcinomatous osteitis there will be no widening of the cortex and no tendency toward bowing in the shaft of the femur.

When the physician still has difficulty in making the differential diagnosis, roentgenographic examination of the skull will sometimes show the characteristic widening of bone in the vertex in cases of osteitis deformans (Fig. 100, *b*), whereas the skull is not involved in metastasis from carcinoma of the prostate gland.

COMMENT AND CONCLUSIONS

These fundamental principles in the diagnosis of tumors involving bone have been enunciated with a view of providing a foundation on which to build by experience and observation a firmer structure of knowledge pertaining to the recognition of tumors of bone and the differential diagnosis of them.

Too much stress cannot be laid on the fact that the roentgenographic method is only one of several methods of diagnosis of this type of lesion. Correlation of all the facts in each patient's history is necessary, and biopsy, when it is necessary, done by a competent pathologist, is imperative before any radical measures are undertaken, if the best interests of the patient concerned are to be served.

Fig. 100.—*a*, Paget's disease of bone (osteodystrophia deformans) in the pelvic region, characterized by a decided widening of the cortical region, *b*, osteodystrophia deformans in the skull, showing characteristic widening of bone in the vertex.

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CONTRAST MYELOGRAPHY

John D. Camp

For practical purposes the roentgenologic signs of tumors affecting the spinal cord may be classified as direct and indirect. The *direct* signs consist of changes in the surrounding vertebral structures due to erosion from pressure by the tumor or actual infiltration by it and calcification within the tumor. The incidence of these changes varies according to the type of tumor but the average incidence for all types is 30 per cent. The *indirect* signs are those observed after the introduction of a contrast agent into the spinal subarachnoid space and this procedure is known as *contrast myelography*. It is used whenever the presence, situation or extent of a tumor cannot be definitely determined by the usual neurologic or roentgenologic examinations. Even though the neurologic localization of a lesion may be definite, it is often desirable to establish precise localization by means of contrast myelography in order that the neurosurgeon may confine laminectomy to the exact level of the lesion. Contrast myelography greatly facilitates the early diagnosis of tumors within the spinal canal before compression of the spinal cord and involvement of the contiguous vertebra have occurred. With modern technic small tumors are easily localized by means of a filling defect in the outline of the contrast agent long before complete obstruction of the cerebrospinal fluid has occurred. In the majority of cases the defect is so characteristic that the extradural, intradural or intramedullary situation of a tumor can be readily determined.

Various agents are available for use in contrast myelography. They include *air, oxygen, iodized oils, iodized solutions* such as are used for intravenous urography and *thorium*

level was used, then small, nonobstructing lesions would become visible by virtue of their space-occupying properties and the resultant filling defects. Odin, Runström and Lindblom shared the same opinion. With this end in view, in about 1930 I recommended the use of 5 cc. of lipiodol for the work because this quantity had been found from previous experience with smaller amounts to be optimal for the most nearly accurate and consistent localization of nonobstructing lesions. Some lesions may be shown with smaller amounts but, on the other hand, a number of large tumors and particularly multiple lesions may be overlooked when amounts less than 5 cc. are used.

That lipiodol is an irritant to the spinal meninges has been fully admitted by early and recent observers. At the Mayo Clinic we have frequently warned against its indiscriminate use and have emphasized that it is contraindicated in frank inflammatory lesions. Nevertheless, the consensus of experienced neurologists and neurosurgeons is that, when lipiodol is used judiciously and in selected cases, its advantages far outweigh any disadvantages that have been recognized. My experience with its use in the recognition of space-occupying lesions affecting the spinal cord and cauda equina indicates that this procedure has attained a degree of accuracy that is equalled by few other diagnostic roentgenologic methods. The indiscriminate use of iodized oil in cases of low back pain or sciatic pain is not recommended. No contrast agent should be used unless the clinical and neurologic examinations indicate the possible presence of an intraspinal lesion that cannot be localized by ordinary clinical procedures.

Technic of Examination.—The *lumbar* injection of iodized oil is preferred because it is easier and safer to carry out than cisternal puncture. It is important that the iodized oil be clear, transparent and only faintly yellow before use. It is desirable that the roentgenologic study be carried out as soon after the injection as possible, because delayed examination and movements of the patient may lead to separation of the mass and formation of droplets. A tilting roentgenoscopic table with appropriate foot and shoulder rests is necessary.

dioxide sol (thorotrast). The ideal contrast agent for this purpose has not been found and each of the aforementioned substances has certain advantages and disadvantages. Some of the latter are serious. The probable situation of the lesion and the possibility of whether or not a block of the cerebrospinal fluid is present will influence the selection of the mediums to be used. These factors will be discussed in the section of this paper in which specific agents are considered. Because the fundamental work relating to contrast myelography was carried out with iodized oil and because the diagnostic criteria so well established for this substance form the basis for the interpretation of changes observed with other agents, iodized oil will be considered first in this discussion.

IODIZED OIL

The use of iodized oil for the roentgenologic visualization of space-occupying lesions within the spinal canal was introduced by Sicard and Forestier in 1922. They employed a 40 per cent iodized poppy seed oil known as "lipiodol." A short time before (1919), Dandy had suggested the injection of air into the spinal subarachnoid space as a means of localizing obstructing lesions, but because certain difficulties attended the use of air he soon abandoned it in favor of the use of lipiodol. Numerous other iodized oils are available but in my experience none has been so satisfactory as lipiodol, the radiopacity and viscosity of which lend themselves especially well to contrast myelography. From the time of its origin until the present decade, lipiodol was thought by many observers to be useful only in the presence of obstructing lesions, and for the demonstration of such it was used in amounts varying from 0.5 cc. to 2 cc. Neurosurgery and knowledge concerning tumors of the spinal cord have developed speedily in the past ten years and it was soon evident that in the interest of better postoperative results, some means of localizing a lesion before obstruction and irreparable damage to the spinal cord had occurred was needed. From my experience I felt that if enough lipiodol to visualize the subarachnoid space completely at any desired

by the degree of tilt of the table and the various curves of the spinal column. If there is a considerable degree of lordosis, scoliosis or kyphosis a greater degree of tilt will be necessary to move the oil over the apex of these curves. A slowing-up of the movement or a transitory arrest of motion due to lordosis, scoliosis or kyphosis should not be mistaken for an organic ob-

Fig. 101.

Fig. 102.

Fig. 101.—Lipiodol outlining normal subarachnoid space in the lower part of the lumbar region and the sacral cul-de-sac.

Fig. 102.—Lipiodol outlining the subarachnoid space in the cervical region of the spinal column.

struction. Normally, a transitory lag will occur when the conus medullaris is reached and again at the peak of the thoracic curve (usually at about the fourth or fifth thoracic vertebra). In the absence of a block in the cervical portion of the spinal column it may be impossible to obtain satisfactory visualization of the entire cervical portion of the canal without

We have recently devised a new table which, although it is of the same height as standard tables, will tilt 90 degrees in either direction. This greatly facilitates the examination and permits a complete study to be carried out in about a half the time formerly required. Some method of quickly recording the roentgenoscopic image on film is highly desirable. If a "spot" film device is not available, excellent films may be made by the sliding of a cassette under the roentgenoscopic screen, delimiting the region by the roentgenoscopic shutters and changing from roentgenoscopic to roentgenologic technic by means of a quick change-over switch on the control panel. In addition to localized films of the lesion, a large film revealing several contiguous vertebrae is necessary in order accurately to establish the anatomic level at which the lesion is situated. This is extremely important when surgical intervention is contemplated, because congenital variations at the lumbosacral junction or the presence of supernumerary lumbar vertebrae may easily mislead the neurosurgeon when he counts the spinous processes for determination of the site of laminectomy. It is necessary that the surgeon and roentgenologist agree on the anatomic level at which the lesion is situated before operation, since otherwise small lesions might be overlooked when laminectomy is not extensive.

The fundamental object of the roentgenoscopic examination is to keep the iodized oil together in one mass and cause it to move caudad and cephalad throughout the subarachnoid space by varying the tilt of the roentgenoscopic table. The examination is commenced with the patient in the prone position, since experience has shown that the oil will flow en masse better when the patient is in this position. The head and feet are fixed by appropriate rests. With the roentgenoscopic screen in position, the head end of the table is elevated and the oil is allowed to flow into the sacral cul-de-sac and collect in one mass (Fig. 101). When this has occurred the foot end of the table is gradually elevated and the cephalad excursion of the oil throughout the lumbar, thoracic and cervical regions is observed. The rate of movement of the oil will be influenced

by keeping the patient's head turned to one side. As the oil flows over the upper thoracic curve it will move up quickly into the cervical region. By returning the table partially toward the horizontal plane at that time, and by careful manipulation of the tilting mechanism the oil can be caused to accumulate in a good-sized mass so that it will fully outline the cervical subarachnoid space (Fig. 102). After visualization of the cervical region has been obtained the table is tilted back to the

Fig. 103.—Roentgenogram made with patient in prone-oblique position to reveal the anterolateral position of a protruded intervertebral disk between the third and fourth lumbar vertebrae.

horizontal position and the return movement of the oil into the cul-de-sac is observed. Defects or questionable defects in the oil shadow should be checked again as the oil moves caudad throughout the suspected region. Any defect to be significant must be persistent or capable of repetition.

After the completion of the examination in the prone position the patient is turned into the supine position and the roentgenoscopic observation is repeated. Any lesion situated anteriorly, such as protruded intervertebral disk, will be re-

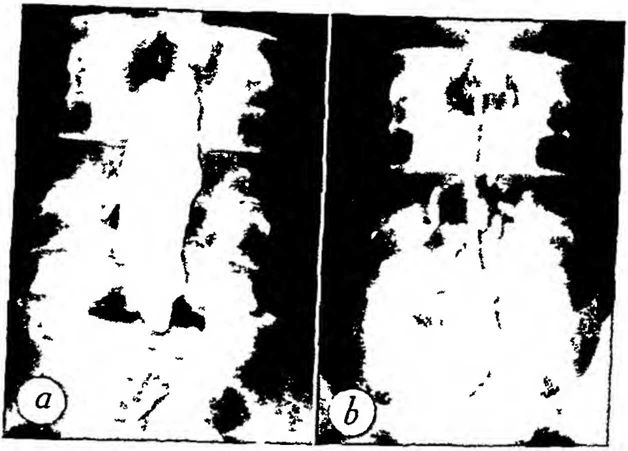

Fig 103 —*a*, Roentgenogram made with patient in the prone position, in which lipiodol reveals a protruded lumbosacral intervertebral disk on the right side, *b*, roentgenogram made with patient in supine position, in which there is no deformity to indicate the presence of a protruded intervertebral disk

Fig 104 —*a*, Intradural meningioma 8 mm in diameter revealed by a defect in the shadow cast by lipiodol, patient in the prone position, *b*, with the patient in the supine position no deformity in the lipiodol shadow appears

some of the oil's passing into the cranial cavity. This can be diminished considerably and completely avoided in some cases

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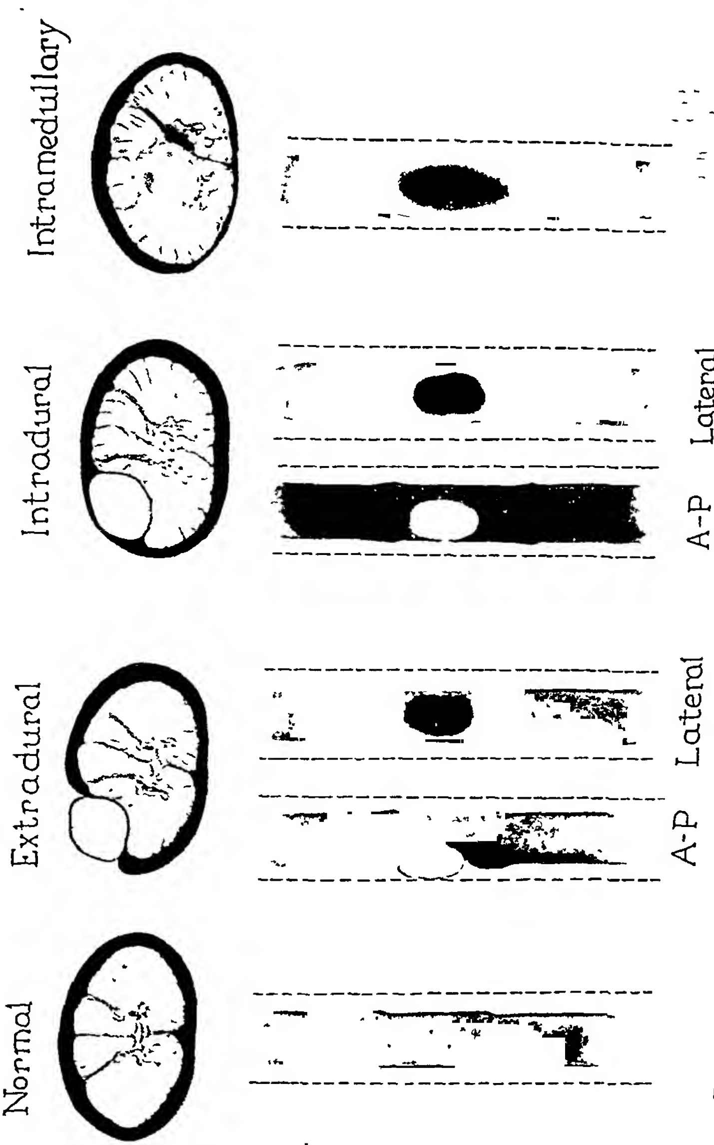

Fig. 106.—Artist's drawing which depicts the characteristic shadow produced by lipiodol in subarachnoid space in a sector of normal spinal cord, and the deformity produced in the lipiodol shadow by extradural, intradural and intramedullary tumors. Lipiodol within the subarachnoid space in indicated in the drawing in black.

vealed best when the patient is in the prone position (Fig. 103, *a* and *b*) and lesions situated posteriorly will show better when the patient is supine. The reasons for this are obvi-

ous, since lipiodol, being heavier than the spinal fluid, will gravitate to the dependent portion of the subarachnoid space. Small lesions may be visible when the patient is in one position and not when he is in the other (Fig. 104, *a* and *b*). The examination is continued with the making of observations with the patient in the lateral and oblique positions, as may appear indicated. Examination with the patient in these latter positions will serve to establish the anteroposterior relationship of

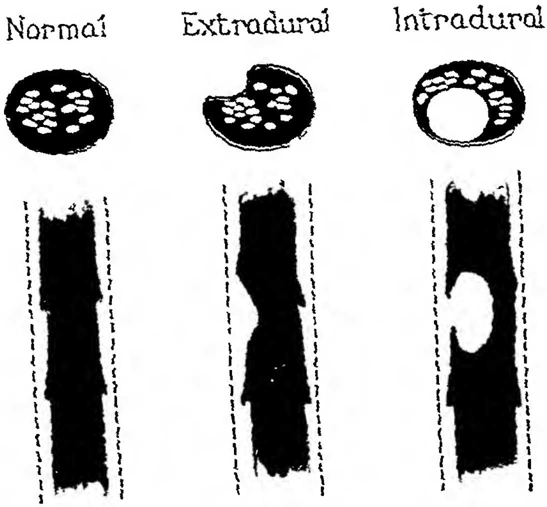

Fig. 107.—Artist's sketch depicting characteristic shadow produced by lipiodol in subarachnoid space *in* normal sector of spinal cord and characteristic defects in lipiodol shadow produced by extradural and intradural tumors affecting the cauda equina. Lipiodol within the subarachnoid space is indicated in the drawing in black. Notice that the various nerves roots lie within the mass of the oil.

any lesion that may be disclosed (Fig. 105). Localized roentgenograms should be made as indicated whenever a defect is observed. To expedite the localization for the neurosurgeon, the exact level of the defect can be denoted on the patient's skin by an indelible mark or a lead indicator which will show in subsequent roentgenograms.

Because of the anatomic relationship of the subarachnoid space to the spinal cord and the dura, it is readily possible in

most instances to determine whether the lesion is extradural, intradural or intramedullary (Fig. 106). Caudad to the conus medullaris it is possible to determine only whether the lesion is extradural or intramedullary (Fig. 107).

Extradural Lesions.—Lesions of extradural origin will produce a corresponding indentation of the lipiodol shadow and the roentgenologic characteristics of such lesions are shown in Fig. 108. When no obstruction or partial obstruction is present the oil will be deflected away from the lesion and by rotation of the patient into the oblique and lateral positions the

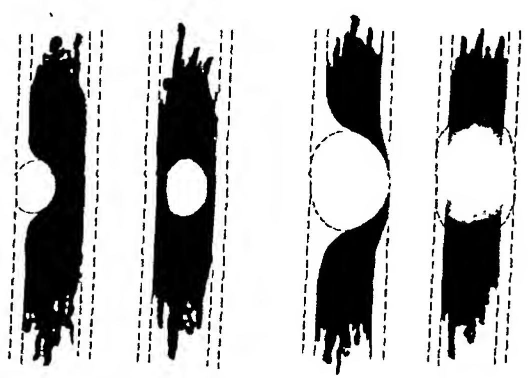

Fig. 108.—Artist's sketch which depicts the characteristic type of deformity in the lipiodol shadow produced by (*left*) a small extradural tumor and (*right*) a large extradural tumor. *Notice that the shadow of the subarachnoid space is not increased in diameter.*

anterior, posterior or lateral position of the lesion may be ascertained readily. When complete obstruction is produced by a lesion, the oil shadow will be pushed away from the lesion, and terminate in an indefinite manner as shown in Fig. 109. It is important to note that the subarachnoid space as revealed by lipiodol is not increased in width by extradural lesions. This is a significant difference from the deformity produced by intramedullary lesions.

Protruded Intervertebral Disk.—The most common extradural lesion is an intraspinal protrusion of an intervertebral disk. This most frequently involves the fourth lumbar or

lumbosacral interspace, but may occur at any level. The deformity of the iodized oil shadow resulting from a protruded intervertebral disk is influenced by the following factors: (1) the position of the protrusion, (2) the size of the protrusion, (3) associated hypertrophy of the ligamentum flavum, (4) changes in the nerve roots (displacement, edema, nonfilling of affected nerve root sleeve) and (5) anatomic variations of the cul-de-sac.

Position of the Protrusion.—Except in unusual cases the protruded fragment is situated in the anterior portion of the

Fig. 109. Intraspinal protrusion of the lumbosacral intervertebral disk. There is a characteristic unilateral, extradural type of deformity in the lipiodol shadow.

spinal canal and will produce its greatest effect on the column of iodized oil when the patient is lying in a prone or prone-oblique position. The classic defect is a sharply defined unilateral rounded indentation of the iodized oil shadow opposite an intervertebral disk (Fig. 109). It occurs in about 65 per cent of cases. Protrusions at the midline when of moderate size may produce only a central defect.

Size of the Protrusion.—Except as the iodized oil deformity may be influenced by the presence of hypertrophy of the ligamentum flavum, the larger the protrusion the greater the obstruction of the subarachnoid space will be. Partial obstruc-

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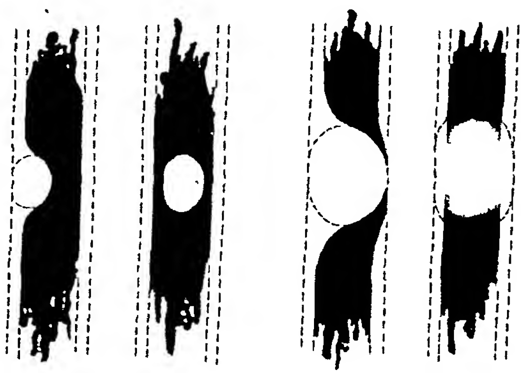

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Size of the Protrusion.—Except as the iodized oil deformity may be influenced by the presence of hypertrophy of the ligamentum flavum, the larger the protrusion the greater the obstruction of the subarachnoid space will be. Partial obstruc-

tion occurs in about 11 per cent of cases and complete obstruction in only about 2.5 per cent of cases (Fig. 110, *a* and *b*). The larger the protrusion, the greater is the tendency toward production of a bilateral deformity, which occurs in about 35 per cent of cases.

Hypertrophy of the Ligamentum Flavum.—This condition is found frequently in association with a protruded interverte-

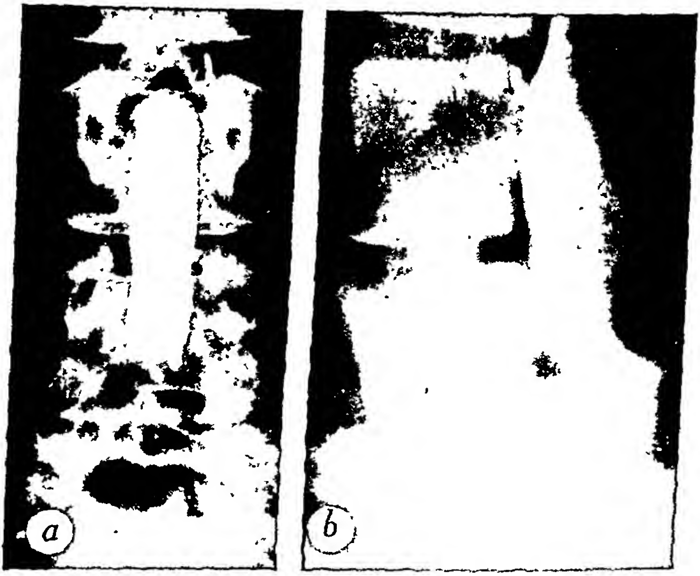


Fig. 110—Complete obstruction of the subarachnoid space produced by a large protruded intervertebral disk situated between the fourth and fifth lumbar vertebrae, *a*, roentgenogram made with patient in the prone position, *b*, roentgenogram in the lateral aspect; note posterior deviation of the lipiodol at the site of protrusion.

bral disk. It usually occurs at the same level as the protrusion, but occasionally may be found at other interspaces. Localized hypertrophy of the ligamentum flavum without coincidental protrusion of a disk is not common. When it does occur it may imitate all the clinical phenomena of a protruded intervertebral disk. Because of the anatomic situation of the ligamentum flavum, this structure when it is hypertrophied will compress the column of iodized oil posteriorly and laterally.

In the lateral view, its presence is characterized by a broad or rounded indentation on the posterior aspect of the shadow of the iodized oil between contiguous laminas. When the patient is in the prone or supine position the hypertrophy is portrayed by a broad indentation of the column of iodized oil, generally

Fig 111.—Intraspinal protrusion of the intervertebral disk between the fourth and fifth lumbar vertebrae, with associated hypertrophy of the ligamentum flavum, with characteristic deformity in the lipiodol shadow: *a*, anteroposterior view, showing bilateral broad defect caused by hypertrophied ligamentum flavum; *b*, lateral view, showing anterior indentation caused by protruded intervertebral disk and indentation on the posterior aspect of the lipiodol column resulting from pressure from the hypertrophied ligamentum flavum.

bilateral but occasionally unilateral. When considerable hypertrophy of the ligamentum flavum accompanies a large protruded disk, the mass of iodized oil is compressed between the protruded disk anteriorly and the hypertrophied ligamentum flavum posteriorly and laterally. The resultant deformity is characteristic (Fig. 111, *a* and *b*).

Changes in the Shadow of Nerve Roots.—In about a third of the cases of protruded intervertebral disk, displacement of shadows of nerve roots will be visible at the site of the protrusion. Abnormal enlargement of a nerve root shadow indicating edema is frequently observed in roentgenograms at or just above the site of a protruded disk (Fig. 112). An early change that results from edema of a nerve root is obliteration

Fig. 112—Complete obstruction of lipiodol produced by an intraspinal protrusion of the intervertebral disk between the third and fourth lumbar vertebrae. The longitudinal defect in the lipiodol shadow is caused by edema of the third lumbar nerve root.

of the usual shadow of the nerve sleeve where the root passes through the dura.

Anatomic Variations of the Cul-de-sac.—Two anomalies of the terminal portion of the cul-de-sac which occur in about 5 per cent of cases may complicate the roentgenologic diagnosis of a protruded lumbosacral intervertebral disk. The first is an anomaly in which the terminal portion of the cul-de-sac is

narrower than usual below the level of the fourth lumbar intervertebral space. In such a case a moderate protrusion of the lumbosacral disk may not deform the narrow subarachnoid space and a large protrusion may produce only a minimal defect. The second anomaly is one in which the cul-de-sac terminates one or two segments more cephalad than usual with or without a variation in its diameter. In a few instances, the cul-de-sac will terminate above the level of the lumbosacral interspace. When either condition is present (especially the

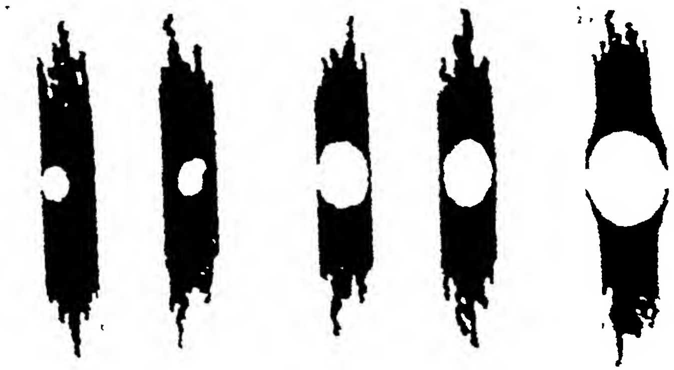


Fig. 115.—Artist's sketch depicting characteristic deformity of lipiodol shadow produced by a small, a medium and a large intradural extramedullary tumor. Notice that the margins of the defect are sharply defined, and that the lipiodol tends to engulf the tumor.

latter), it is obvious that a lumbosacral protrusion may not be disclosed by means of iodized oil or any other contrast agent.

Intradural Lesions.—Because of the intimate relationship of the arachnoid to the dura and pia any extramedullary lesion originating internal to the dura may for practical consideration by the roentgenologist be thought of as being situated within the cavity containing the iodized oil. Thus, the tumor will deform the oil shadow in much the same way as a polyp within the stomach will displace the surrounding barium (Fig. 115). When the tumor is small and no obstruction is present, the oil will engulf the tumor mass which will be revealed as a sharply defined defect in the shadow of the oil (Fig.

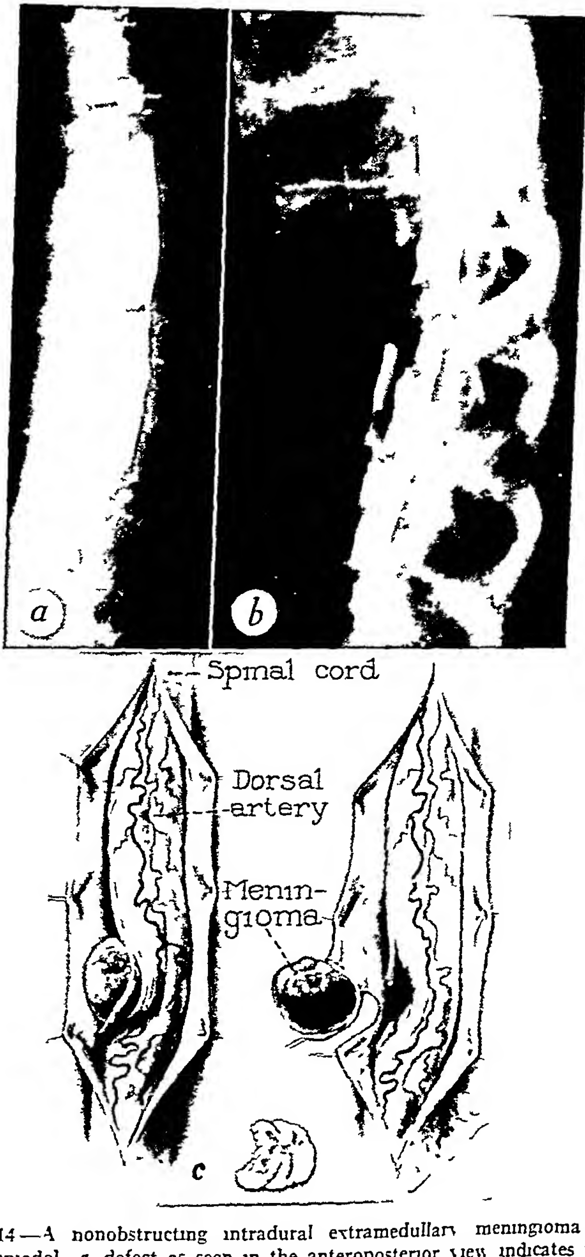


Fig 114—A nonobstructing intradural extramedullary meningioma revealed by lipiodol, *a*, defect as seen in the anteroposterior view indicates that the tumor is situated on the left side, *b*, defect as seen in the lateral view indicates that the tumor is situated anteriorly, *c*, artist's sketch of this tumor Notice that the tumor is anterior to, and to the left of, the spinal cord

114, *a*, *b*, and *c*). As the tumor increases in size, the defect is correspondingly enlarged until obstruction takes place. At this point the sharply defined "half moon-shaped" deformity so characteristic of intradural lesions (Fig. 115) is most obvious.

Rarely can the roentgenologist predict the cytologic aspects of an intradural tumor on the basis of the myelographic findings. Exceptions to this occur in the presence of very vascular tumors (arteriovenous fistula, hemangioma) and neurofibroma-

Fig. 115.—Intradural extramedullary neurofibroma opposite the twelfth thoracic vertebra, producing complete obstruction to lipiodol in the spinal subarachnoid space. This lateral view reveals a "half-moon" filling defect characteristic of completely obstructing intradural extramedullary tumors.

tosis. In the former the tortuous pulsating defect of enlarged blood vessels is easily identified (Fig. 116, *a* and *b*) and in the latter, the defects of multiple variously sized tumor masses and enlarged nerve roots portray the identity of the underlying condition (Fig. 117, *a* and *b*).

Intramedullary Lesions.—Fundamentally, these lesions when occurring cephalad to the conus produce a more or less fusiform enlargement of the spinal cord (Fig. 118). Edema

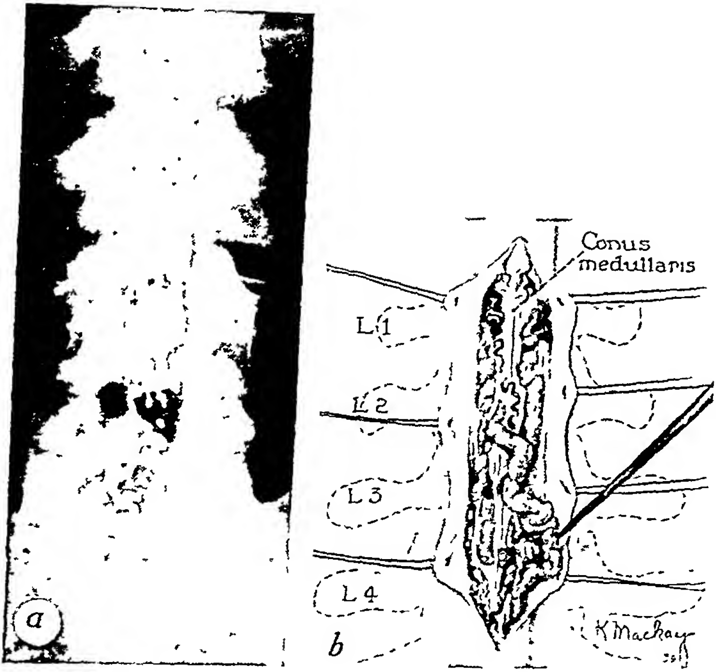


Fig 116—*a*, Roentgenographic appearance of arteriovenous fistula, in which an irregular filling defect is produced by the tortuous, dilated vessels; *b*, artist's sketch of this lesion as seen at operation

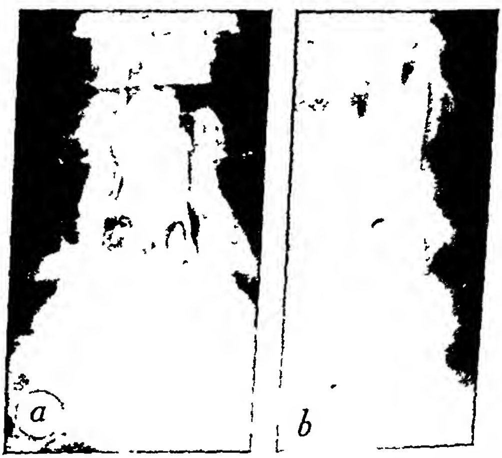


Fig 117.—Neurofibromatosis, *a*, anteroposterior view and *b*, lateral view, revealing enlarged nerve root shadows and tumor masses

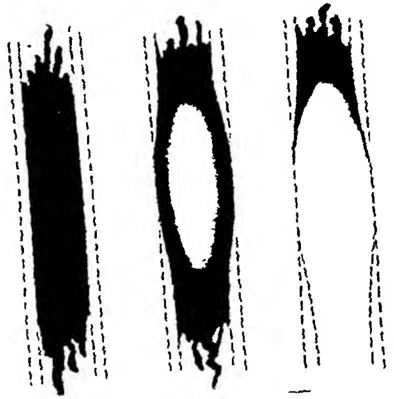


Fig. 118.—Artist's sketch, depicting (*left*) shadow produced by lipiodol in the normal subarachnoid space and (*center* and *right*) defects in the lipiodol shadow produced by an intramedullary tumor.

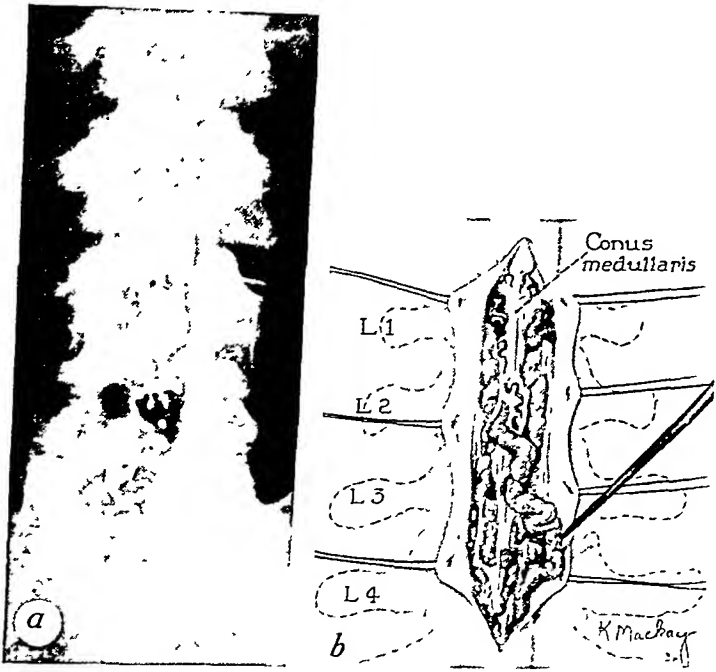
Fig. 119.

Fig. 120.

Fig. 119.—Anteroposterior view of an intramedullary tumor which is producing a fusiform filling defect and obstruction of lipiodol. Notice the shadows of tortuous blood vessels on the surface of the expanded spinal cord.

Fig. 120.—Anteroposterior roentgenogram of multiple intraspinal protrusions of the intervertebral disks between the third and fourth lumbar vertebrae, as revealed by defects in the lipiodol shadow.

of the cord and dilatation and tortuosity of overlying blood vessels may occur secondarily. Because of the expanded spinal



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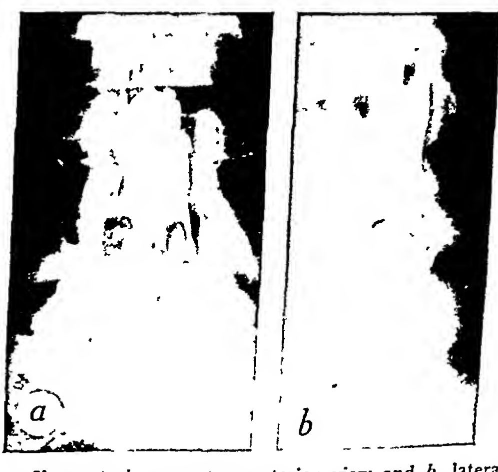


Fig 117.—Neurofibromatosis; *a*, anteroposterior view and *b*, lateral view, revealing enlarged nerve root shadows and tumor masses.

with lipiodol is influenced greatly by the experience of the examiner and the thoroughness of the examination. It must be emphasized that the method is essentially a roentgenoscopic procedure, which constitutes a distinct advantage in that the presence and characteristics of a suspected defect may be checked repeatedly. Additional roentgenograms of course should be made of all defects. Examinations based on the use of inadequate amounts of iodized oil and roentgenograms alone frequently are valueless and often are misleading.

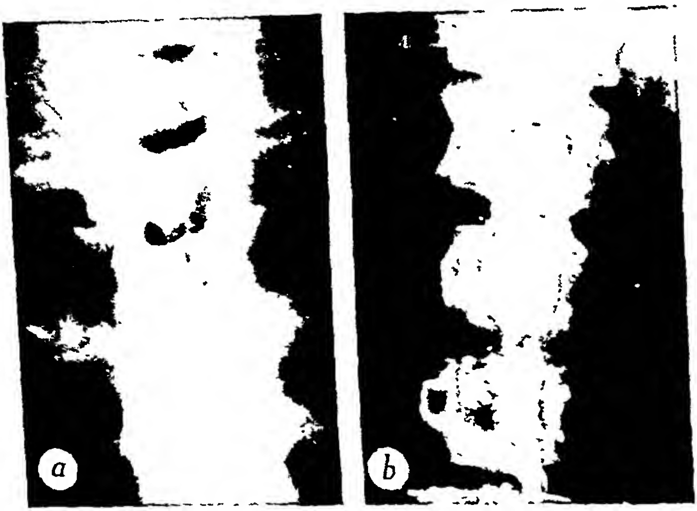


Fig. 121—*a*, Intradural extramedullary tumor situated at the first thoracic vertebra as revealed by lipiodol; *b*, multiple protruded intervertebral disks in the lumbar region (same patient as is concerned in *a*).

Details of the errors occurring in a group of 417 studies made with lipiodol have been reported by Addington and me. In that study the injection of lipiodol into the subarachnoid space localized the lesion with an approximation of accuracy of 96.8 per cent and identified the character of the lesion with an approximation of accuracy of 90.8 per cent.

Reactions to the Injection of Lipiodol.—It is difficult to appraise accurately the amount of reaction, if any, that a patient may experience after the injection of lipiodol into the

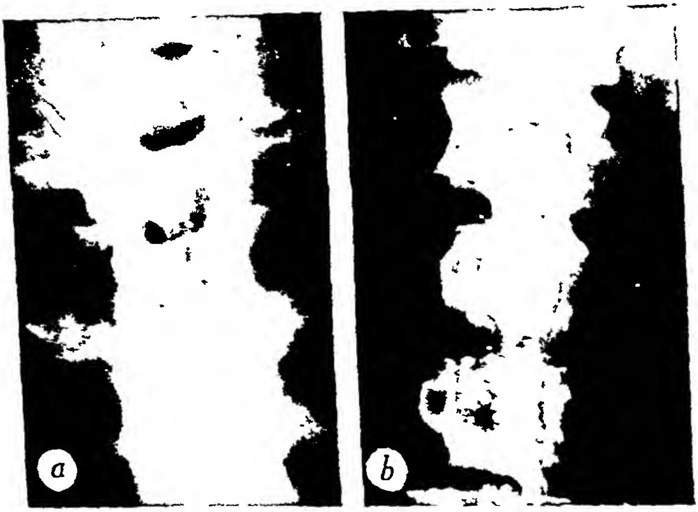
cord, the surrounding subarachnoid space is secondarily compressed and there results a defect in the lipiodol shadow which more or less conforms to the fusiform expansion caused by the tumor (Fig. 119). The margins of the defect are indistinct and fade out as they approach the point of greatest expansion. When the lipiodol moves into the region of an intramedullary tumor, the oil shadow is split and the two lateral portions will diverge around the expanded cord.

Caudad to the conus the spinal cord is replaced by the individual roots of the cauda equina (Fig. 107). Intramedullary tumors arising from individual nerve roots of the cauda equina cannot be distinguished roentgenographically from primary tumors of nerve roots (neurofibroma) and both will produce the myelographic image of an intradural tumor. Edema of individual nerve roots frequently results from pressure secondary to a protruded intervertebral disk and occasionally, from a tumor. This is identified by an enlargement of the shadow of the affected nerve root (Fig. 112).

Multiple Tumors.—Multiple tumors affecting the spinal cord are not common, but since they have been found in 4 per cent of tumors of the spinal cord[1] the roentgenologist should study the entire spinal canal when lipiodol is used, regardless of whether or not a lesion is found at the level under suspicion clinically. Multiple tumors may produce confusing clinical signs and unless they are recognized before operation, the surgical results may prove disappointing, since if the lesions are separated by several segments, some may be overlooked. Multiple protrusions of the intervertebral disks occur in 12 per cent of cases of protruded disks[1] (Fig. 120) and they usually but not necessarily involve contiguous segments. A patient who has a protruded intervertebral disk may also have a tumor of the spinal cord in a region contiguous to or remote from that of the protrusion (Fig. 121, *a* and *b*) and I have had experience with several such cases.

Accuracy of Examinations Made with Lipiodol.—Like any diagnostic procedure which is based on personal observations and deductions, the accuracy of the examination made

with lipiodol is influenced greatly by the experience of the examiner and the thoroughness of the examination. It must be emphasized that the method is essentially a roentgenoscopic procedure, which constitutes a distinct advantage in that the presence and characteristics of a suspected defect may be checked repeatedly. Additional roentgenograms of course should be made of all defects. Examinations based on the use of inadequate amounts of iodized oil and roentgenograms alone frequently are valueless and often are misleading.



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Reactions to the Injection of Lipiodol.—It is difficult to appraise accurately the amount of reaction, if any, that a patient may experience after the injection of lipiodol into the

subarachnoid space. In most instances the examination is antedated by recent lumbar puncture and under such circumstances it is hard to say which symptoms are due to one procedure and which to the other. In the great majority of cases in which a positive diagnosis was made, operation was carried out immediately after the examination or so soon afterward that it became impossible to judge symptoms because of the interjected surgical procedure. On the basis of my experience with lipiodol over many years, it is my opinion that the reaction which follows the use of 5 cc. of the medium is no greater than that occasioned by the use of 2 cc., and, because 5 cc. will reveal lesions more nearly accurately than 2 cc. or less, I believe it is the quantity of choice. Two of my colleagues, Walsh and Love, have studied the meningeal response after the subarachnoid injection of lipiodol and they wrote:

"Our findings corroborate the findings of others that a transitory meningeal irritation occurs following the injection of iodized oil into the subarachnoid space. It is, however, of mild degree, as evidenced by the changes in the spinal fluid. It is equalled, as far as the acute phase goes, by the reaction to the intraspinal insufflation of air, in which Thurzó and Nagy reported an increase of from 400 to 3,000 cells in the spinal fluid of man with an accompanying increase of total protein, and with concomitant signs of meningeal irritation. It is well known and has been demonstrated often that the subarachnoid injection of any foreign substance causes a meningeal reaction, the severity and duration of which depend on the irritating properties of the substance. When the reaction in the subarachnoid space to iodized oil is compared to the known reaction to numerous other agents, iodized oil may be classified as a substance provoking a mild and benign meningeal irritation.

"We have seen no clinical reactions to iodized oil that might not have been produced by a spinal or cisternal puncture with the withdrawal of spinal fluid alone and we agree in this respect with Globus. In the large number of laminectomies for removal of protruded intervertebral disks that have been performed at the Clinic at intervals varying from a few minutes

to two years after the intraspinal injection of iodized oil, no visible evidence of irritation of the meninges or nerve roots attributable to the iodized oil alone has been noted at operation. It is probable, however, that the injection of iodized oil into the subarachnoid space in certain cases in which partial or complete obstruction of the circulation of the spinal fluid exists might accentuate the clinical symptoms. Since in these cases operation is indicated, and should immediately follow the localization of the lesion, permanent damage is not done."

Medicolegal Objections to Radiopaque Oil.—The greatest objection to the use of an iodized oil is a psychologic one, based on the fact that unless it is removed the oil remains permanently visible. Since the history of many patients suffering from conditions of the back is complicated by injuries and insurance or medicolegal entanglements, it is good judgment not to attempt the use of a radiopaque oil until all other practical methods of clarifying the diagnosis have been used. Resourceful attorneys and malingering patients may use roentgenograms which reveal the shadow of the remaining oil as a tangible basis for claiming aggravation of symptoms and such roentgenograms may have a profound effect on a sympathetic jury.

The methods of examination which have been described herein apply to the use of other iodized oils as well as lipiodol, and the objections to their use are the same. Iodized solutions such as those used for intravenous urography cannot be recommended for use in the subarachnoid space because of their marked irritant effect on the meninges. When they are used in dilutions that avoid this, their radiopacity is so diminished that they are of no practical value.

THORIUM DIOXIDE SOL

Thorium dioxide sol, although it is an excellent radiopaque medium, is open to criticism because of its radioactivity and inherent danger when it is left within the body. In my experience with animals, thorium dioxide sol has proved to be a severe meningeal irritant and at the Clinic we have therefore

refrained from using it for human beings. By devising a method for its rapid elimination from the spinal subarachnoid space, Nosik has used thorium dioxide sol rather successfully for the visualization of protruded intervertebral disks in the lower lumbar portion of the spinal canal. His original report should be consulted for details concerning use of this medium. In brief, the technic consists of the injection of 10 cc. of thorium dioxide sol into the lower lumbar part of the subarachnoid space. The media is maintained in that situation by keeping the patient in a semirecumbent position. Roentgenograms of the area are made. Roentgenoscopy is not attempted. After the examination the spinal puncture needle is reintroduced and with forced spinal drainage provoked by the intravenous administration of an 0.45 per cent hypotonic solution of sodium chloride the thorium dioxide sol is removed. Subsequent roentgenograms and chemical examination of the spinal fluid recovered indicate that practically all of the medium is eliminated.

Roentgenograms made with this medium are excellent, and permit visualization not only of the lesion but of the nerve roots comprising the cauda equina. The method is useful primarily for the demonstration of lesions in the lower lumbar portion of the spinal canal, and for localization of protruded intervertebral disks in particular. Its *disadvantages* lie in the fact that generally only the three distal lumbar segments can be visualized. Because it is rapidly diluted by the spinal fluid when it is moved into other portions of the spinal canal, thorium dioxide sol is not satisfactory for the detection of tumors involving the conus medullaris or spinal cord. This may be a serious disadvantage, for it is not always possible to distinguish by clinical means tumors situated at and just below the conus from protruded intervertebral disks at the fourth lumbar or lumbosacral interspaces. Thorium dioxide sol is a severe irritant when it is injected into subcutaneous tissues and, when it is used, every effort should be made to keep it from entering the epidural space, from which it cannot be recovered.

MYELOGRAPHY WITH AIR

The use of air or oxygen for the visualization of the spinal subarachnoid space has been revived in recent years and this procedure has certain *advantages:* (1) there are no contraindications to its use, (2) the air is resorbed after the examination, (3) there is no irritating effect from the injection other than that resulting temporarily from the injection, (4) roentgenoscopic observation is not necessary and since the findings are recorded on roentgenograms these may be studied at the examiner's convenience.

On the other hand, there are certain *disadvantages* to the use of myelography with air: (1) the procedure is unsatisfactory for nonobstructing lesions which are situated above the level of the conus medullaris, (2) the shadows produced with air and defects revealed by it are less distinct than those observed when iodized oil is used, their interpretation is correspondingly more difficult and unless the examiner is experienced in the procedure the likelihood of error is greatly increased, (3) roentgenoscopic verification of any defect is not possible, (4) inconclusive results of examination are much more frequent when air is used than when iodized oil is used and (5) experience has shown that the results of studies made with air (especially when such results are negative) are less accurate than the results obtained with iodized oil.

Experience indicates that if the suspected level of a lesion is *at or above* the conus medullaris, the use of air or oxygen will not help in the diagnosis unless obstruction of the subarachnoid space has occurred, because it is very difficult to retain air or oxygen in a desired position in the thoracic or cervical portion of the spinal canal. Its use in these regions is further complicated by the superimposition of the shadow of air in the trachea, larynx and pharynx, which renders interpretation of resulting shadows difficult or impossible. Iodized oil is therefore the medium of choice for the demonstration of lesions situated at or above the conus medullaris.

Statistics indicate that the great majority of protruded intervertebral disks occur in the lumbar and lumbosacral

regions, where they are accessible to examination by means of either air or iodized oil. Since there is a reasonable chance that the protruded disks may be disclosed by means of air or oxygen it probably is good judgment to attempt to localize them by this method before iodized oil is resorted to. If the results of the studies made with air are positive, much has been gained and if the results are inconclusive or unsatisfactory, iodized oil may still be used. If studies made with air result in negative findings and the history and neurologic examination indicate the probable presence of a lesion, the surgeon must then decide whether to check the findings in the myelogram made with air by means of iodized oil or to advise laminectomy on the basis of the history and neurologic observations.

Technic of Myelography with Air.—The methods and principles of the examination are essentially the same whether air or oxygen is used. Oxygen is more rapidly absorbed from the subarachnoid space than ordinary air, and the likelihood of headache following the procedure is considerably reduced. At the Clinic, in our experience with the use of air, it has been found that postmyelographic headache may be prevented or quickly aborted by the patient's use of an oxygen mask at the first sign of discomfort.

Patients who are to undergo myelography with air are placed in the lateral recumbent position on the *x*-ray table. The shoulders of the patient are supported by a comfortable and well-padded shoulder rest and the thighs and feet are fixed by means of a traction band that passes about the thighs and is adjusted by means of a windlass. A lumbar puncture needle is inserted in the first or second lumbar interspace and 10 cc. of spinal fluid is removed for cytologic study. The spinal fluid needle is maintained in position and the table is tilted 40 degrees toward the head (Fig. 122, *a* and *b*). A 20 cc. Luer syringe is now attached to the needle by means of a rubber connector and 10 cc. of air is injected. The syringe is then removed and spinal fluid is allowed to drain from the needle. After the collection of each additional 10 cc. of fluid a corresponding amount of air is injected and this procedure

Fig. 122.—Myelographic examination carried out with air; a, lateral view of patient on x-ray table tilted to 40 degrees for the making of a lateral roentgenogram; b, view of same patient from above. Notice the padded shoulder rests and the windlass, with traction band passing around the thighs for support of the patient while he lies in an inclined plane.

is repeated until spinal fluid ceases to flow. When this point is reached the back of the sacrum is tapped vigorously with the heel of the fist to release any fluid that may be trapped in the sacral cul-de-sac by an air lock. Frequently, an additional 5 to 15 cc. of fluid may be obtained by this procedure. The injection is completed by the addition of 10 cc. more air than cubic centimeters of fluid removed. At least 40 cc. of air is needed for a satisfactory examination. The needle is then withdrawn and the puncture wound is sealed with collodion cotton. With the patient still in the lateral recumbent position, and with the table at an angle of 40 degrees, stereoscopic lateral roentgenograms (14 by 17 inches or about 36 by 43 cm.) are made. A cross-table stereoscopic shift is used to avoid overlapping of the shadows of the intervertebral spaces by the vertebral bodies. The patient is next turned over into the supine position and stereoscopic anteroposterior roentgenograms (14 by 17 inches) are made by means of a cross-table stereoscopic shift (Fig. 123, *a* and *b*). The table is then tilted back to an angle of 10 degrees and the patient is transferred to a surgical carriage on which pillows have been placed to maintain an elevated position of the pelvis and lower part of the spinal column. The patient is next transferred to his room and placed in a bed, the foot end of which has been elevated by blocks. After the roentgenologic examination, the patient is cautioned not to raise his head; this warning is given so that a sudden movement of air into the cranial cavity may be avoided. The patient is kept in bed for twenty-four hours after the examination and an oxygen mask is used as indicated.

Early in this work at the Clinic additional roentgenograms with the patient in various oblique positions were made, and exposures with a horizontal *x*-ray beam were used. Since they revealed no information in addition to that obtained from the routine anteroposterior and lateral stereoroentgenograms, we have discontinued to use them routinely. Experiments with varying degrees of exposure indicate that the air shadows are best portrayed when that part of the roentgenogram which

Fig. 123.—Myelographic examination carried out with air; a, lateral view; b, view from above. The patient lies in the supine position for the second roentgenogram, and the table is tilted to 40 degrees.

depicts the lumbar portion of the spinal column itself is slightly overexposed.

Interpretation of Observations.—Because of the great difference between the radiographic density of iodized oil and

Fig. 124.—Normal results of myelographic examination with air; *a*, anteroposterior view, in which the subarachnoid space is revealed by a shadow of diminished density (air) within the spinal canal; *b*, lateral view, in which the air shadow is in intimate contact with the posterior border of the vertebral bodies and the intervertebral disks.

air or oxygen, the defects that occur when the latter mediums are used are much less obvious and frequently overlooked by the inexperienced examiner. Normally the subarachnoid space

is revealed as a homogeneous shadow of diminished density extending throughout the spinal canal. In the usual examination for determination of the presence of a protruded intervertebral disk, the subarachnoid space becomes visible up to about the tenth thoracic segment. This is influenced naturally by the amount of air injected, which in the average case is between 40 and 60 cc. In the anteroposterior view the lateral margins of

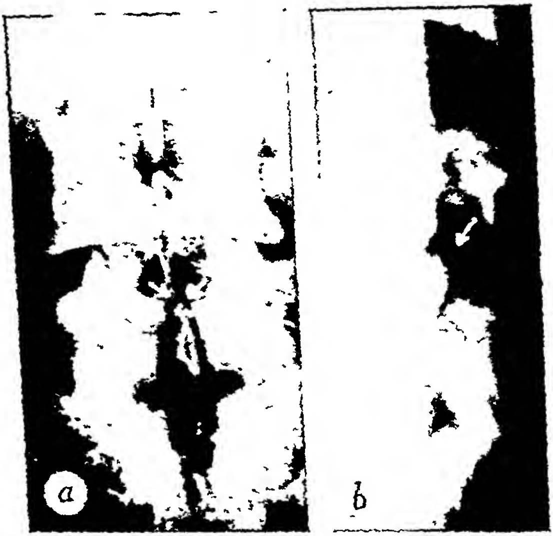

Fig. 125.—Myelogram made with air, revealing a protruded intervertebral disk between the fourth and fifth lumbar vertebrae; *a*, anteroposterior view, in which bilateral narrowing of the air shadow at the level of the protrusion can be seen; *b*, lateral view, in which the protruded disk has produced an indentation on the anterior aspect of the air shadow, the most common type of deformity encountered in air myelograms when a protruded intervertebral disk is present.

the subarachnoid space are well defined and are parallel throughout (Fig. 124, *a* and *b*). The nerve sleeve shadows which are commonly seen when iodized oil is used are not frequently portrayed by air. The nerve root shadows of the cauda equina occasionally may be demonstrated. In the lateral view the anterior border of the subarachnoid space is in close apposition to the contiguous surface of the vertebral bodies and intervertebral disks. Posteriorly, the margins of

the subarachnoid space are less clearly defined, especially where the shadows of the pedicles and laminas are superimposed upon it.

The classic deformity produced by a *protruded intervertebral disk* is an indentation corresponding to the protrusion, on the anterior aspect of the air column opposite the involved

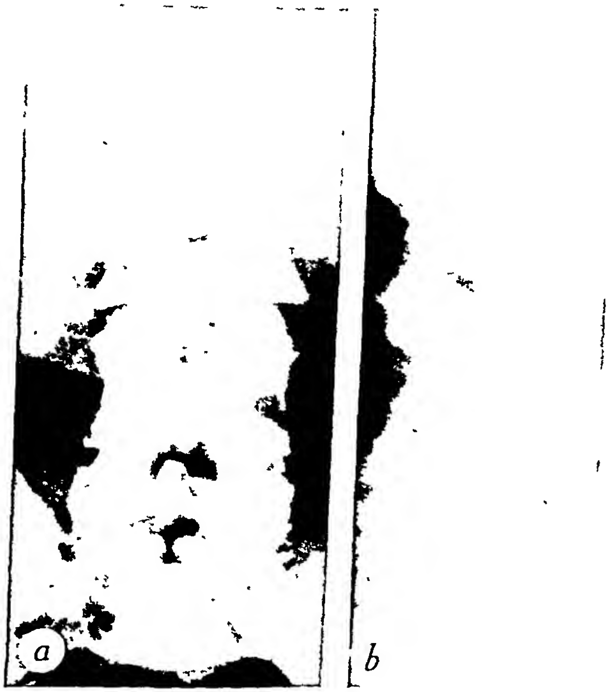

Fig. 126—*a*, Anteroposterior view; *b*, lateral view, myelogram made with air in which a protruded intervertebral disk is seen between the fourth and fifth lumbar vertebrae. The continuity of the air shadow opposite the site of the lesion is interrupted and appears to be obliterated.

interspace. *In most cases the deformity is best defined in the* lateral view (Fig. 125, *a*). In the anteroposterior view the protrusion may be evident as a unilateral indentation (Fig. 125, *b*), or as a contralateral displacement of the air column. In many instances the continuity *of the air shadow appears to* be interrupted opposite the site of the protruded disk in the

anteroposterior view (Fig. 126, *a, b*). Associated *hypertrophy of the ligamentum flavum* may augment the deformity and produce an indentation on the posterior aspect of the air column in the lateral view and a bilateral narrowing of the air shadow in the anteroposterior view. In many instances the air column will seem to terminate in a fusiform manner opposite the level of the protrusion. Compression of the air shadow between the

Fig 127.—*a*, Lateral myelogram made with air of a protruded intervertebral disk at the lumbosacral junction; posterior displacement of the air column and fusiform termination of the air shadow with apparent obstruction opposite the midportion of the body of the fifth lumbar vertebra can be seen; *b*, myelogram made with iodized oil, same patient as in *a*, in which a deformity in the anterior aspect of the lipiodol column, produced by the protruded disk, can be seen. The amount of iodized oil in the cul-de-sac caudad to the lesion indicates that there is no obstruction, as might be suggested by the myelogram made with air (*a*).

protruded disk anteriorly and the hypertrophied ligamentum flavum posteriorly gives rise to the fusiform termination of the air shadow (Fig. 127, *a*). An erroneous impression that the subarachnoid space is obstructed frequently is deduced from this deformity. The deformity can be explained by the fact that the air in the subarachnoid space is not under pressure; because of its specific gravity it is unable to force itself between

the disk and ligament. The absence of an obstruction in such cases is easily demonstrated if lipiodol is used subsequently (Fig. 127, *b*). The weight of the lipiodol is sufficient to carry it past the site of the protrusion, except of course in the 2 per cent of cases in which actual obstruction occurs. The frequent inability of air to outline the subarachnoid space caudad to a protruded disk is a disadvantage, since in such a circumstance a second protrusion distal to the first cannot be excluded. When such a situation involves the fourth lumbar disk it is not so serious, since both the fourth and lumbosacral interspaces can be explored by the neurosurgeon in the course of laminectomy involving only the fifth lumbar vertebra. However, when the situation involves the second or third lumbar interspace more extensive laminectomy than usual may be necessary for the surgeon confidently to exclude other protrusions distal to the one revealed in the myelogram made with air.

A *tumor* affecting the spinal cord should be suspected if the protein content of the spinal fluid is considerably elevated. If the lesion is within the lower thoracic or lumbar portions of the spinal canal and no obstruction is present, the mass may be revealed by virtue of its contrasting density when myelography with air is used. However, because of the numerous shadows of bony structures that are superimposed on the air-filled subarachnoid space, the outline of a nonobstructing tumor may be entirely obscured. When obstruction of the subarachnoid space has occurred in any portion of the spinal canal, myelography with air carried out caudad to the obstruction will clearly define the point of obstruction and frequently will outline the distal contour of the tumor itself. When the tumor is in the lumbar region, the air may be introduced cephalad to the lesion and in this case the upper contour of the tumor will be revealed by the air at the point of obstruction (Fig. 128). Unless obstruction is present, myelography with air is not a practical procedure for the localization of tumors situated above the conus medullaris.

Evaluation of the Procedure.—Myelography with air has its greatest value in that group of cases in which a deform-

ity or lesion is revealed by the procedure. In my experience a lesion has been found by the neurosurgeon at the site of the deformity in about 90 per cent of such cases in which the patients have been operated on. My greatest objection to the procedure is based on the fact that a negative result of a myelogram made with air has proved to be comparatively unre-

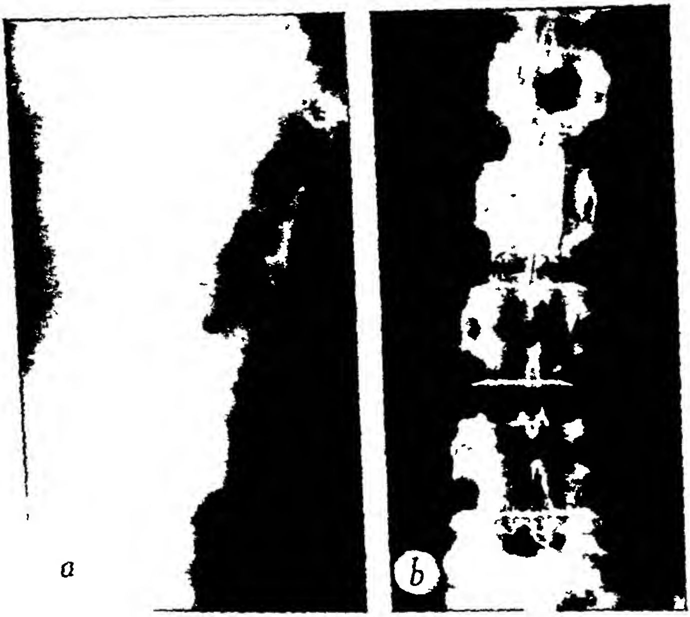

Fig 128—a, Lateral myelogram made with air, in which a large neurofibroma originating at the third lumbar vertebra and extending slightly below the level of the lower margin of the second lumbar vertebra can be seen; the rounded upper border of the tumor is clearly defined at the point of obstruction by contrast with the air which was injected cephalad to the lesion; b, anteroposterior view, lipiodol within the subarachnoid space cephalad to the tumor, serving to confirm the level at which the tumor mass which was revealed by air (a) is situated.

liable. In my experience a lesion has been found by the surgeon in a high percentage (74 per cent) of cases in which the patients were operated on regardless of the negative results of a myelogram made with air. This fact should not be lost sight of by the clinician when he appraises the results of such studies made with air. When the use of air (or oxygen) reveals either

a deformity that will not account for the patient's symptoms, or a lesion, the level of which is not compatible with the symptoms, the results should be confirmed by myelography with iodized oil before treatment by laminectomy is advised. Additional experience with air myelography undoubtedly will result in some improvement of the degree of diagnostic accuracy of the procedure. However, because of certain basic limitations of the method, it is not likely that its efficiency will ever equal that attained by myelography carried out with iodized oil.

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TUMORS OF THE SCALP AND SKULL AND THEIR SIGNIFICANCE AS REVEALED BY ROENTGENOGRAMS

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TUMORS OF THE SCALP

Clinically the diagnosis of tumors involving the scalp presents little difficulty in the average case. The size of the lesion, its mode of onset, color, consistency, mobility and duration in most instances will suffice to divulge its character. Nevertheless, in spite of this seeming simplicity of diagnosis, there are certain affections in which changes in the scalp are related so intimately to lesions or structural defects in the underlying calvarium that an accurate diagnosis can be rendered only after roentgenologic examination. The importance of a roentgenologic study of the skull in all cases in which surgical intervention is contemplated for a lesion of the scalp should not be underestimated, for frequently seemingly innocent nodules in the scalp are expressions of systemic, osseous or intracranial disease and the blind excision of such nodules may be hazardous to the patient or embarrassing to the surgeon.

With a properly adapted roentgenographic technic the soft tissues of the scalp, the calvarium or its contents may be examined at will. A soft or low voltage roentgenographic technic will reveal the soft tissues of the scalp to best advantage but, since the average roentgenogram of the head is made predominantly for bone detail, the surrounding soft tissue shadows will not be visible unless the film is examined in front of a small spotlight.

Roentgenographically the scalp is revealed as a more or less homogeneous shadow of increased density surrounding the calvarium. In the occipital region where the mass of tissue is

thicker, shadows representing the epidermis, subcutaneous tissue, fascia and muscles may be identified. Shadows due to the hair may or may not be visible. When the normal appearance of the hair has been modified by the presence of braids, dye, oil, other preparations or blood, shadows of varying density may result. Some of these, when superimposed on the shadow of the calvarium, may be mistaken for intracranial or osseous pathologic changes unless stereoscopic roentgenograms are available.

Tumors of the scalp may be grouped as congenital, developmental, neoplastic, traumatic and inflammatory.

Congenital and Developmental Lesions.—The most common congenital tumors of the scalp are vascular and may be grouped as nevi, hemangiomas, arteriovenous fistulas and sinus pericranii. Many of these lesions are associated with underlying variations in the vascularity of the calvarium which are readily apparent roentgenologically. In a certain variety of hemangioma known as *Sturge-Weber syndrome*, the lesion is distributed in a more or less triangular manner in the parietal and occipital regions of the scalp. Large, tortuous vessels are also present over the brain in the corresponding region and within the brain cortex there occurs extensive calcification which has a characteristic appearance. The calvarium on the affected side is thicker and not as fully expanded as on the unaffected side, indicating impaired development of the underlying brain.

Sinus pericranii is a congenital anomaly in which one or more emissary veins connect with the large intracranial blood sinuses through abnormal foramina in the skull. It is characterized by a soft fluctuant swelling which increases in size when the patient is recumbent and may be reduced by pressure. Roentgenographically the lesion is associated with a rarefaction or perforation of the calvarium at the site of the soft tissue mass with widening of the contiguous diploe. Since the lesion is located most frequently in the forehead, sagittal suture or occiput, it may be confounded with a meningocele or encephalocele. The latter conditions, however, represent herniations

of intracranial structures which always occur in suture lines or at suture junctures. The bone defect at the point of perforation is rounded and sharply demarcated and there is no increased vascularity, in contradistinction to sinus pericranii.

Neoplastic Lesions.—With one or two exceptions the common *benign tumors* of the scalp have no distinguishing roentgenographic characteristics and are revealed only as discrete rounded enlargements of the shadow of the scalp. *Sebaceous cysts* occasionally may undergo partial calcification and *lipomas*, because their fatty structure is translucent to roentgen rays, may be identified by their rarefied appearance as it stands out in contrast to the surrounding soft parts.

Malignant tumors of the scalp may be primary or metastatic and, before involvement of the contiguous calvarium has occurred, they may not be distingushed roentgenographically from benign tumors. Sooner or later secondary invasion of the contiguous bone occurs and the usual moth-eaten appearance of malignant lesions will be obvious in the roentgenogram. If the lesion is of low grade and complicated by infection, bone reaction incident to the infection may mask the significant characteristics of malignancy. Malignant tumors secondary to lesions of the calvarium will be discussed under tumors of the calvarium.

Traumatic Tumors.—*Hematomas* of the scalp are fairly frequent and are revealed as a diffuse swelling of the soft tissue shadow at the point of injury. They, of course, may or may not be associated with an underlying fracture of the skull. *Lacerations* of the scalp may cause confusing shadows when one is searching for skull fractures. Air within the cleft of a laceration may imitate a fracture line and overlapping of the edges of a laceration may produce a shadow of increased density simulating the overlapping edges of a depressed fracture.

Inflammatory Tumors.—Inflammatory tumors of the scalp result from infections of the scalp, underlying calvarium, mastoid and frontal sinuses. Generally speaking, the clinical history will point to the diagnosis. The shadow of the soft parts is increased in thickness in the affected area and may

thicker, shadows representing the epidermis, subcutaneous tissue, fascia and muscles may be identified. Shadows due to the hair may or may not be visible. When the normal appearance of the hair has been modified by the presence of braids, dye, oil, other preparations or blood, shadows of varying density may result. Some of these, when superimposed on the shadow of the calvarium, may be mistaken for intracranial or osseous pathologic changes unless stereoscopic roentgenograms are available.

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mask early involvement of underlying bone if the exposure to roentgen rays is not increased in proportion to the size of the soft tissue swelling.

TUMORS OF THE CALVARIUM AND CONDITIONS THAT MAY SIMULATE THEM ROENTGENOLOGICALLY

The soft tissues of the scalp are related so intimately to the underlying calvarium that irregularities in contour and tumors affecting the latter structure often produce changes in the scalp that may be difficult to differentiate from primary lesions of the scalp. Tumors of the calvarium and conditions that may simulate them roentgenologically may be classified as in the accompanying tabulation.

TABULATION

TUMORS OF THE CALVARIUM AND CONDITIONS THAT MAY SIMULATE THEM ROENTGENOLOGICALLY

Congenital anomalies
- Encephalocele and meningocele
- Vascular anomalies
  - Diploe
  - Pacchionian depressions
  - Sinus pericranii
  - Emissary veins and foramina
- Parietal foramina

Developmental variations
- Muscular attachments
- Bilateral symmetrical thinning
- Frontal sinuses
- Thickening of sutures and at junctures

Primary tumors of the calvarium
- Osteomas
  - External table
  - Inner table
    - Benign hyperostosis
- Epidermoid
- Hemangioma
- Sarcoma
  - Fibrosarcoma

Metastatic tumors
- Carcinoma
- Myeloma
- Neuroblastoma
- Endothelioma
- Hodgkin's disease

Secondary to intracranial disease
- Glioma
- Meningioma
- Hemangioma
- Epidermoid

Inflammatory
- Osteomyelitis—primary or secondary
  - Tuberculosis
  - Syphilis
- Mucocele

Traumatic
- Osteoma formation
- Aseptic necrosis

Systemic disease
- Leukemia
- Blood dyscrasias
- Parathyroid disease
- Paget's disease
- Xanthomatosis

Congenital Anomalies.—*Encephalocele* and *meningocele* are the most significant anomalies in this group. These herniations through the skull always occur in sutures or at sutural junctures. The bony defect at the point of herniation is always round and the margins are defined sharply and increased slightly in density. When the herniation occurs at the frontonasal junction, the lesion must be distinguished from a mucocele. The latter lesion occurs usually slightly to one side of the midline and produces an expansion of the affected frontal sinus with thinning of its walls. The presence of a normal frontonasal juncture will distinguish a mucocele from a meningocele.

Vascular anomalies of the structure of the calvarium are exceedingly common and frequently are interpreted erroneously as evidence of a contiguous brain tumor or metastatic malignant lesion. Variations in the markings of the diploe are generally more or less symmetrical. A marked unilateral increase in size and distribution of the channels of the diploe may be significant but at most is only suggestive evidence of an intracranial tumor. More or less sharply defined indentations of the inner table at the site of pacchionian bodies may vary considerably in size and depth. Large indentations, which exhibit irregularities resulting from the irregular surface of the contiguous pacchionian body, may be confounded with the changes of bone associated with meningioma, epidermoid tumor or a small dural herniation of the brain. The vascular markings leading to a pacchionian depression may be increased in size, thus making its differentiation from significant lesions more difficult. The condition of sinus pericranii has been discussed already. Enlarged emissary veins and their foramina are not of themselves likely to be mistaken for a neoplasm but they may be associated with vascular tumors of the scalp.

Congenital parietal foramina which occur in the posterosuperior portion of the parietal bones are practically always symmetrical, a fact which should point to their congenital origin. The condition is familial and the size of the foramina may vary considerably in different cases. Roentgenographically the foramina are well defined on each side of the sagittal

suture. Even though they may reach a diameter of 3 cm. each, seldom are they seen to fuse across the midline as one large parasagittal defect. Their symmetrical nature may suggest bilateral trephine openings.

Developmental Changes.—Variations in the development of the cranial bones and sutures may give rise to unusual or asymmetrical contours of the skull. Premature union of various sutures gives rise to such conditions as *oxycephaly, scaphocephaly,* and so forth. When these conditions are severe, they may be complicated by an associated cerebral hernia. Lack of development of one cranial bone gives rise to an irregularity at its sutural junction with its neighbor. Sometimes this is referred to as *dysostosis cranii.*

A developmental *symmetrical thinness of the parietal bones* in their superolateral portion occurs in about 0.4 per cent of skulls. It is essentially a developmental absence of the diploe in the affected region and tends to be familial. It is visualized best in anteroposterior roentgenograms of the head. In the lateral projection the thin areas are revealed as zones of rarefaction. The transition from the thin area to the part of normal thickness is palpated readily on the outside of the skull in each parietal region. A few instances of unilateral involvement have been observed. In one such case the unilateral thinning was thought to be evidence of erosion from an underlying brain tumor. This mistake should not be made, however, because pressure erosion from a brain tumor involves the inner table, while developmental thinness results in a flattening of the external table and loss of underlying diploic structure.

Irregularities in the ossification or variations in the thickness of cranial sutures may be reflected in variations of the radiopaque density of the involved suture. They are of no pathologic significance as a rule. Similarly an increase in density of bone along sutures, most notably the squamosal and lambdoidal, in persons past middle age is of no significance. Variations in the size of the occipital protuberance are common and should not be mistaken for osteomas. Slight bony prolifer-

ation along the nuchal line in heavy muscular persons is fairly common and should not be interpreted as disease of bone.

Primary Tumors of the Calvarium.—*Osteomas.*—By far the most common tumors involving the calvarium are osteomas. They occur singly or multiply and may involve the external or internal tables or both. Generally speaking, two varieties, a spongy type and a dense ivory-like type, may occur. An uncommon form is the diffuse dense osteomatous thickening of the frontal bone and occasionally of contiguous bones known as *leontiasis ossea*.

Except from the standpoint of cosmetic appearance, pure osteomas arising from the *external table* are of no pathologic significance. They may vary in shape from a small, discrete, bulbous projection arising from a narrow base to a broad flat mass which arises from a wide base. They produce a corresponding bulging of the scalp tissues. Roentgenographically an attempt should be made to project them in profile in order to make sure that both tables of the skull are not involved. Small osteomas of the external table frequently are confounded with discrete tumors of the scalp until a roentgenographic examination is made. Care must be taken lest the shadow of a wen or other superficial tumor, projected on the calvarium, be interpreted as an ivory-like osteoma. If a profile projection of the tumor is always made, this mistake should not be possible.

Osteomas involving the *inner table* of the skull may be single or multiple. They usually are of the sclerotic variety and may be broad and flat, or discrete, rounded or pointed projections, the base of which blends with the internal table. Single osteomas may arise from any point of the internal table but are most common contiguous to sutural junctions and along the parasagittal region. Because the calvarium frequently is involved secondarily by a contiguous underlying meningioma which produces an osteomatous thickening of the inner table, diploe and external table, all osteomas of the internal table should be looked on with suspicion and a contiguous meningioma excluded. Small ledges of bone forming the borders of

arterial grooves, particularly at points of arterial branchings, should not be mistaken for true osteomas. A common form of multiple osteoma has been described variously as *benign frontal hyperostosis* or *hyperostosis cranii.* This condition consists of multiple, variously sized, stalactite-like osteomas projecting from each side of the midline of the frontal bone. The condition varies greatly in extent and may involve even the parietal bones. The exact cause of this condition is not known. Many patients who have benign frontal hyperostosis complain of persistent headache. The bilateral symmetrical appearance of benign frontal hyperostosis should distinguish it from osteomatous formation secondary to meningiomas, which usually is unilaterally distributed.

Epidermoid Tumor and Hemangioma.—Other fairly common benign tumors of the skull are the epidermoid tumor and hemangioma. The epidermoid tumor results from an inclusion of ectodermal cells, usually within the diploic structure. The slow growth of the epidermoid tissue results in a rounded area of rarefaction with expansion of the diploe. The margins of the lesion are sharply defined and increased in density. Occasionally when the tumor is large, it may break through the external table, producing a corresponding soft tissue mass beneath the scalp. Likewise, an epidermoid may erode through the inner table of the skull and press against and displace the contiguous surfaces of the dura and brain. Fairly frequently, epidermoid tumors contain plaque-like areas of calcification similar to the calcification observed in tumors of Rathke's pouch. Hemangiomas of the skull exhibit the same roentgenologic manifestations as hemangiomas involving the skeletal system elsewhere. They are characterized by a honeycomb architecture of the involved bone with widening of the intratrabecular spaces and widening and increase in density of the trabeculae throughout the lesion.

Sarcoma.—Primary *osteogenic sarcoma* of the calvarium is rare but, when it does occur, it exhibits the same roentgenologic manifestations as the disease in other portions of the skeleton. The calvarium at the location of the tumor is infiltrated and

destroyed in the characteristic manner of malignant lesions and the scalp is invaded secondarily, with the production of a soft tissue tumor. *Fibrosarcoma* involving the calvarium is more frequent than the primary osteogenic variety. This lesion produces a localized area of infiltrated destruction of varying size and frequently imitates metastatic malignant lesions and occasionally secondary involvement of the calvarium due to *meningioma*.

Metastatic Tumors.—Metastatic *carcinoma* involving the skull exhibits the destructive changes common to this lesion in other portions of the skeleton. Metastatic carcinoma of the calvarium is imitated closely by multiple myeloma and it is frequently impossible to differentiate the two on the basis of the roentgenologic findings. Carcinoma of the thyroid fairly frequently provokes varying degrees of proliferation of the external table which results in coarse, lace-like projections in a corresponding soft tissue mass of the scalp. These lesions in the calvarium are often solitary. Metastatic *neuroblastoma* usually exhibits an involvement of the calvarium which is irregularly rarefied and increased in density. Proliferative changes throughout the external table, with the production of parallel radiating lines of newly formed bone, are a characteristic manifestation of this lesion. Multiple metastatic nodules within the scalp are usually also present. The presence of a tumor in the adrenal area and generalized involvement of the skeleton by changes similar to those in the calvarium point to the diagnosis. Malignant destruction of the skull may result from direct extension of an endothelioma of the scalp or by lymphatic extension from a malignant lesion within the nasal accessory sinuses or soft tissues of the face. The presence of the primary lesion should serve to identify the nature of the secondary lesion in the calvarium.

Cranial Changes Secondary to Intracranial Disease.—The inner table of the skull may be involved by local pressure erosion from an expanding intracranial tumor as in the case of a *glioma*, or the overlying calvarium may be infiltrated secondarily as in the case of a contiguous *meningioma*. In the

presence of clinical signs of an intracranial lesion, localized thinning of the internal table of the skull may be of great diagnostic importance in determining the site of the brain lesion. About 50 per cent of meningiomas are associated with osteomatous involvement of the contiguous calvarium. The meningioma cells penetrate the haversian canals of the calvarium and produce varying degrees of bone reaction and osteomatous formation. Meningioma involving the vault usually gives rise to a spongy type of osteoma which varies in size from a localized area 1 cm. in diameter to large osteomatous masses. Considerable increased vascularity is usually evident throughout the area of involved bone. Osteomas secondary to a meningioma contiguous to the floor of the skull are more prone to be small and sclerotic. Frequently they do not exceed 0.5 cm. in diameter. They occur especially about the tuberculum sellae or olfactory groove. Meningiomas arising along the sphenoidal ridge frequently produce a diffuse sclerotic thickening of the lesser wing of the sphenoid and anterior clinoid process.

Large *vascular lesions* involving the meninges and cortex of the brain frequently are associated with secondary dilated vascular channels in the overlying calvarium and, when there is an accompanying vascular lesion of the scalp, the calvarium may be perforated by dilated vessels. In the presence of *unilateral atrophy* of the brain the corresponding half of the calvarium is underdeveloped and increased in thickness. This results in an asymmetrical appearance of the calvarium which is very obvious in films made in the anteroposterior or posteroanterior view. In the presence of *meningocele* or *encephalocele*, roentgenograms will reveal a sharply defined, rounded defect in the calvarium which always occurs at a sutural junction or within a suture. It most frequently involves the posterior portion of the skull and the associated soft tissue mass is readily apparent.

Inflammatory Lesions of the Calvarium.—*Primary osteomyelitis* of the calvarium is usually the result of antecedent trauma in which the skull is exposed or penetrated. A

more common form of osteomyelitis is that arising secondarily to a lesion elsewhere, particularly in the frontal sinus or mastoid. It occasionally may follow an infected craniotomy wound. Infection of the calvarium due to *tuberculosis, typhoid fever* or *syphilis* may occur but is not common and syphilitic osteomyelitis is observed much less frequently than it was formerly. A *mucocele* arising in the frontal sinus which produces an expansion of the frontal sinus and pressure erosion of the contiguous portion of the frontal bone should be distinguished from primary lesions within the frontal bone, particularly epidermoid tumors and meningoceles pressing through the frontonasal junction. The presence of inflammatory disease in the frontal sinus and the presence of the expanded frontal sinus will point to the diagnosis of mucocele.

Traumatic Lesions.—The various types of *fracture* of the skull will not be discussed in this paper. The importance of searching for a fracture in the presence of a hematoma of the scalp has been mentioned in an earlier part of this paper. Rarely, *osteomatous thickening* of the external table may result from previous localized trauma to the calvarium. Because of the many variations in the external contour of the skull which occur normally, the diagnosis of an osteoma as a result of previous trauma should be made with reservation unless there is roentgenographic evidence that the osteoma was not present at the time of the injury. A rare form of sequela from localized trauma of the calvarium is *aseptic necrosis*. This results in an irregular, rarefied, more or less cystic type of lesion at the point of injury and may be very difficult to differentiate from a localized infection of the calvarium.

Lesions of the Calvarium Secondary to Systemic Disease.—Other than metastatic malignant lesions, the calvarium is involved frequently in such conditions as leukemia, blood dyscrasia of childhood, hyperparathyroidism, Paget's disease and xanthomatosis. In the *blood dyscrasia* of childhood and in *leukemia*, the calvarium exhibits a diffuse, irregular type of osteoporosis and similar changes can be demonstrated elsewhere in the skeleton. In the presence of erythroblastic ane-

mia and sickle cell anemia, sunburst-like proliferative changes are produced in the external table and the diffuse involvement of the external table of the entire calvarium serves to distinguish the condition from the focal proliferative changes that may result when the calvarium is involved secondarily by a meningioma.

Hyperparathyroidism results in a diffuse granular decalcification of the entire calvarium, with a loss of sharpness of detail of the bone trabeculae and contour of the inner and external tables. In advanced cases, small cystic areas may also be observed.

The calvarium is involved commonly in *Paget's disease of bone* (osteitis deformans). This condition is characterized by the combination of a rarefied and condensed osteitis. The diploe of the calvarium is widened and replaced by fibrous tissue within which may be observed multiple nodules of sclerotic bone. The skull is increased considerably in thickness and as a result of the softening of the calvarium an invagination of the base of the skull may result. A less common manifestation of Paget's disease of the calvarium is *osteitis circumscripta* which now is regarded as an early manifestation of the common form of Paget's disease. In the osteitis circumscripta variety of Paget's disease the involved area of the calvarium is decreased in density. The margins of the lesion are demarcated fairly well and there is a generalized loss of calcium in the affected area. Later the usual roentgenographic signs of osteitis deformans will develop in the lesion. Generally when the osteitis circumscripta type of Paget's disease is observed in the skull, the characteristic roentgenographic signs of Paget's disease can be demonstrated in other portions of the skeletal system, particularly the tibia and pelvis.

The *Schüller-Christian syndrome* of xanthomatosis is observed most commonly in children and the characteristic changes in the skull consist of multiple plaque-like areas of rarefaction with sharply defined borders. These may or may not be associated with contiguous tumors within the scalp. Exophthalmos and diabetes insipidus may or may not be pres-

ent. Roentgenographic study of the remainder of the skeletal system will reveal similar lesions. The lesions are radiosensitive and, after adequate roentgen or radium therapy, these zones of destruction will be replaced by bone of normal appearance. Because of the excellent results afforded by radiation therapy it is important to differentiate this condition from metastatic malignant lesions and in cases of doubt a biopsy of one of the tumor nodules is justifiable.

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ROENTGENOLOGIC DIAGNOSIS OF GASTRIC ULCER

B. R. Kirklin

Until scarcely more than two decades ago diagnosticians canvassing the grave lesions of the stomach that might be present in a given case gave first consideration to gastric ulcer. This can be accounted for perhaps by the fact that at that time the anatomic and pathologic lines separating benign gastric ulcer from ulcerous carcinoma and from duodenal ulcer were drawn less often and less sharply than they now are, and thus gastric ulcer received unwarranted emphasis in the practice and literature of medicine. It is now well known that the incidence of gastric ulcer is far below that of ulcerous carcinoma and much farther below that of duodenal ulcer, but impressions derived from the past still make it difficult sometimes for clinicians and roentgenologists to approach the diagnosis of gastric ulcer with the degree of caution appropriate for the relative infrequency with which this lesion occurs.

Pathology.—The favorite *seat* of gastric ulcers is on the posterior wall near, sometimes immediately on, the lesser curvature in the vicinity of the angular incisure. But often they are situated on the posterior wall distant from the curvature, or near the pylorus, and exceptionally they may occur on the anterior wall or greater curvature or elsewhere, but they are seldom, if ever, found above the plane of the esophageal opening. As a *rule* ulcers are single, but rarely there may be two or more. With respect to their *morbid anatomy* as discerned roentgenologically, gastric ulcers may be classed in two groups: namely, *penetrating* ulcers that have excavated the gastric wall to varying depths, and *perforated* ulcers that have burrowed through the wall and into organs or tissues outside the stomach, thus producing an extragastric pocket. Penetrating ulcers vary in diameter from 1 or 2 mm. to 2 cm. or

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more. Perforated ulcers may become sealed off at the serosa and are then indistinguishable roentgenologically from penetrating ulcers. *Accessory pockets* resulting from perforation are extremely rare. Most often the pocket is in the liver, but it may be in the pancreas, spleen or abdominal wall. Pockets vary in size, but their greatest diameter seldom exceeds 3 or 4 cm.

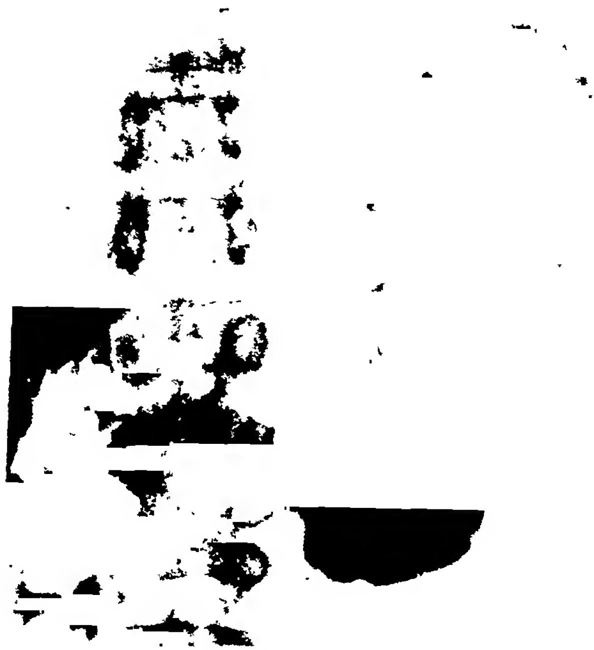

Fig. 129.—Niche of benign ulcer on lesser curvature just above the angle. Considerable antral spasm.

Roentgenologic Signs of Ulcer.—The basic and indispensable roentgenologic sign of ulcer is the barium filled crater of the ulcer, the *niche*, or its exaggerated form, the *accessory pocket*. When the internal surface of the stomach is thinly coated with barium, the niche appears in the face view as a dense spot amid the mucosal relief. Even ulcers that are mere shallow erosions are likely to be visible as persisting flecks on the mucosal pattern. After the stomach is filled with the sus-

pension of barium, the niche of a penetrating ulcer, if favorably situated, can be seen as a budlike prominence on the gastric silhouette, projecting beyond the normal line of the lumen, or if the ulcer is on the posterior or anterior wall distant from either curvature (Figs. 129, 130, 131 and 132), a face view of the niche may be obtained by compressing the stomach to thin out its opaque content. As a rule, the mucosal margin of a benign ulcer is rather evenly rounded, and the base of the

Fig. 130.—Niche of benign ulcer on lesser curvature above angle. Rather marked prepyloric spasm with hypertrophy of the pyloric muscle.

crater is smoothly hemispherical. Usually, also, the accessory pocket of a perforated ulcer is rather regularly ovoid or spherical, and when ovoid it is likely to be pendulous. Often the suspension exhibits an upper fluid level with an air bubble above, and barium may remain in the pocket after the stomach is empty.

Secondary manifestations that commonly accompany gastric ulcer stimulate the examiner to search for their cause and are of considerable value in differential diagnosis. Often the

rugae in the field about the ulcer are accentuated and converge toward the crater. Usually the ulcer is tender to pressure over the niche. Almost invariably the stomach is of hook form, and often the pyloric end is curled toward the median line (Fig. 132). In most cases peristalsis is fairly active and sometimes

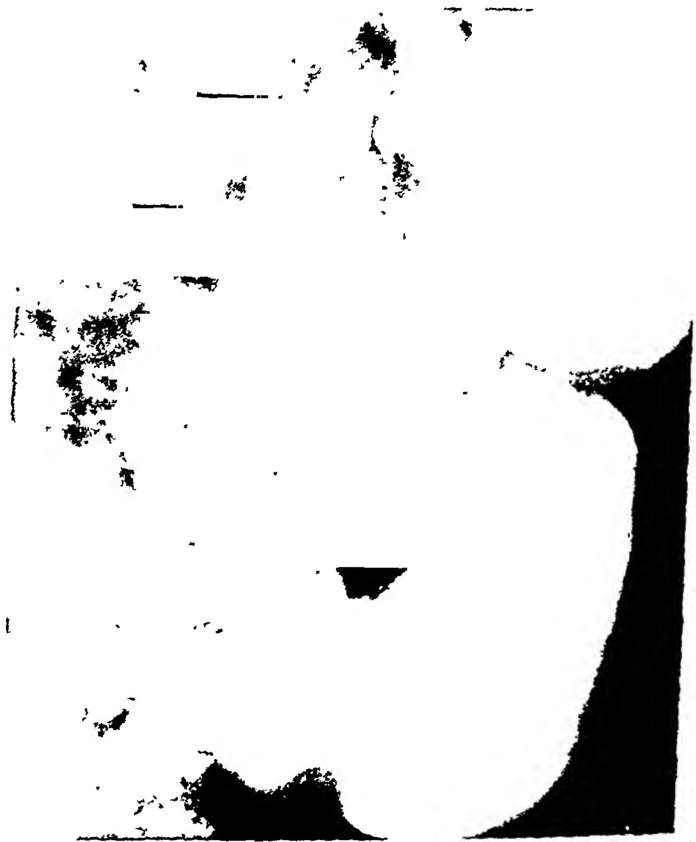

Fig. 131.—Niche of benign ulcer rather high on lesser curvature with spastic hour-glass deformity.

disorderly as a result of the increased irritability of the stomach. *Gastrospasm* in its varied forms is a striking and common accompaniment of ulcer. One form, a deep and narrow indentation of the greater curvature in the plane of the ulcer (Fig. 131), was at one time regarded as a good index, but it occurs

only rarely and is not always significant of ulcer. A much more common variety of gastrospasm, regardless of the situation of the ulcer, is manifested by narrowing of the antrum and blurring of the antral shadow (Figs. 129 and 130). Often the pylorus also is spastic; it opens less freely and less frequently than under normal conditions, and evacuation of the stomach is retarded (Fig. 132).

Fig. 132.—Rather large ulcer niche on lesser curvature with marked gastrospasm. Spastic contraction of lesser curvature producing snail form of stomach. Obstruction due to pylorospasm

In arriving at a diagnosis of ulcer the first task of the examiner is to confirm the presence of a niche or pocket and exclude simulants of either. The shadow of a niche or pocket is constant as to size and form and persists or recurs at the same site. The bulge on the lesser curvature between two peristaltic waves resembles a niche only momentarily for it progresses with the waves. A small mass of barium in the small bowel near the stomach may imitate a niche, but its position changes when the angle of view is altered or the stom-

ach is manipulated. Secondary signs without a niche never warrant a diagnosis of ulcer, for they may result from other diseases or functional disorders.

Differentiation from Malignant Disease.—When it is clear that an ulcerous lesion is present, the differential diagnosis of benign ulcer from *ulcerating carcinoma* and *malignant ulcer* becomes highly important. A small, deeply ulcerated carcinoma has some resemblance to a benign ulcer, but the

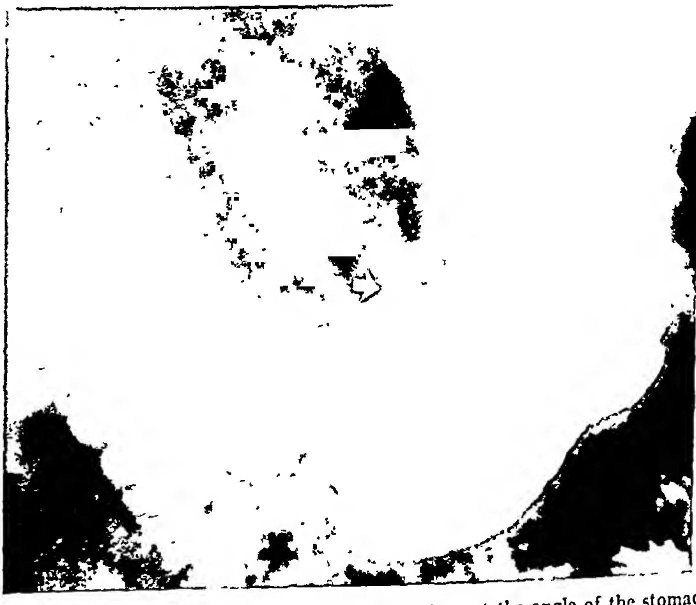

Fig. 133.—Large malignant ulcer on lesser curvature at the angle of the stomach.

former is characterized by demonstrable elevation of the border around the ulcerous excavation, the latter of which is within the gastric lumen, and by absence of the secondary signs that accompany benign ulcer. (See section on Gastric Cancer.) Distinction of benign from malignant ulcers in which the element of tumefaction is not apparent frequently occasions difficulty. In general, benign ulcer is characterized by regularity of the base and mucosal margin of the crater, accentuation and convergence of rugae adjacent to the ulcer, tenderness to pres-

size and spastic accompaniments. In contrast, malignant ulcer commonly is marked by irregularity of the crater (Fig. 133), effacement of adjacent rugae, lack of tenderness to pressure and absence of gastrospasm. Ulcers with craters having a diameter exceeding 2.5 cm. usually, but not invariably, prove to be malignant (Fig. 134). Perforated ulcers with accessory pockets are seldom malignant. Most ulcers on the greater

Fig. 134.—Large malignant ulcer on lesser curvature below angle.

curvature are found to be malignant. Ulcers on the posterior wall remote from the lesser curvature and ulcers near the pylorus are more likely to be malignant than those seated in the vicinity of the angular incisura. Ulcer near the pylorus is especially hard to identify, often its niche cannot be discerned clearly, and the deformity of the antrum resembles that produced by early carcinoma (Fig. 135).

From 10 to 15 per cent of ulcers that seem roentgenolog-

ically to be benign prove nevertheless to be malignant, and both clinician and surgeon should understand thoroughly that a roentgenologic diagnosis of gastric ulcer, *implying that the* lesion appears to be benign, is never to be construed as an assertion that malignancy can confidently be excluded.

The *effect of medical management* on ulcers as indicated by subsequent roentgenologic examination is a valuable test of

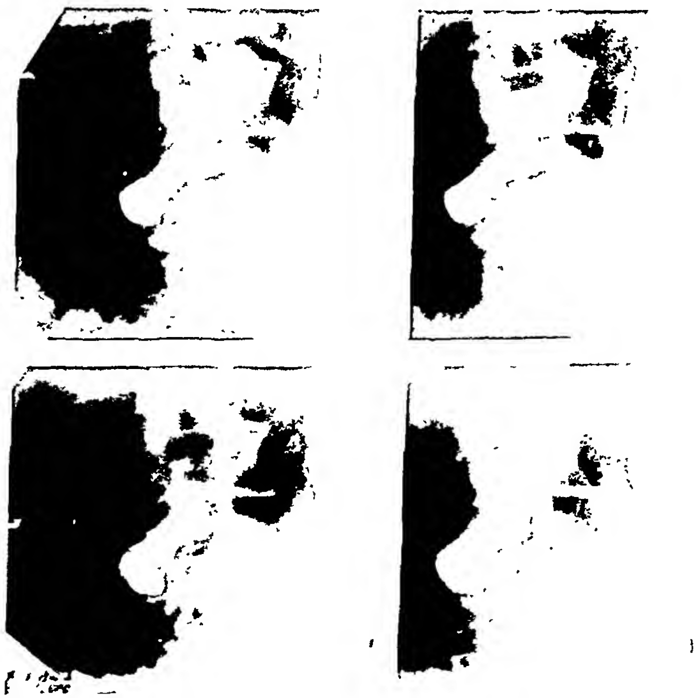

Fig. 135.—Benign prepyloric ulcer with marked spasm.

their character, for diminution or disappearance of the crater is strong evidence that the ulcer is benign. However, the test cannot be relied on implicitly, for occasionally the crater of a malignant ulcer fills with granulations or detritus and thus is obliterated. Hence, every patient who has apparently benign ulcer should be kept under observation until the nature of the lesion is established beyond reasonable doubt.

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ROENTGENOLOGIC DIAGNOSIS OF GASTRIC CANCER

B. R. Kirklin

With current technics, which commonly include roentgenoscopic study of the stomach and careful inspection of its internal relief as revealed by a thin coating of barium, practically all gastric cancers that could be seen macroscopically can be disclosed by roentgenologic examination. This is not to say, however, that all cancers of the stomach can be diagnosed as such, for the degree of accuracy with which their malignant character can be determined depends to a considerable extent on their size, morphology, histologic variety and situation.

Pathology.—*Cellular proliferation* with resulting *tumefaction* is a primary characteristic of cancer, and a majority of the lesions are frank tumors. But cancer is also characterized by ulceration, and this factor is scarcely less common than tumefaction. Consequently most cancers are ulcerating tumors. Occasionally ulceration is so dominant that the element of tumefaction cannot be discerned even on close scrutiny of the excised specimen, and morphologically the lesion must be classed as an ulcer. Thus cancers range, with many intermediate gradations, from tumors to ulcers.

Histologic variations affect the factors of tumefaction and ulceration. Soft *mucoid*, or *medullary*, cancers are markedly tumefactive, but they also tend to ulcerate deeply. *Scirrhous* cancer infiltrates and thickens the gastric wall, but usually tumefaction is not striking, and ulceration is likely to be shallow though extensive. The size and situation of the lesion, whatever its morphology or histologic character may be, affects the emphasis with which its signs are manifested and the readiness with which it can be disclosed and identified.

Roentgenologic Signs of Gastric Cancer.—*Advanced Cancer.*—Advanced *mucoid cancer* usually produces a roentgenologic syndrome that is pathognomonic. In most cases it appears as a gross mass projecting from a wide base far into the gastric lumen. As a rule, the tumor is pitted with multiple

Fig 136—Rather extensive carcinoma in lower half of stomach with some ulceration

ulcerous excavations that are visible as pseudoniches or irregularities of the tumor's internal margin. Occasionally the tumor is largely destroyed by ulceration. The involved portion of the gastric wall is sharply demarcated from the uninvolved portion (Fig. 136). In most cases the form and size of the stomach

are not notably altered and its capacity is lessened only to the extent that the mass intrudes into the lumen.

Advanced scirrhous cancer also gives rise to a characteristic picture. With its tendency to originate in the pyloric segment and to encircle the stomach, the viscus often assumes the shape of a funnel. One variety of scirrhous cancer, sometimes included under the designation "fibromatosis," may convert the

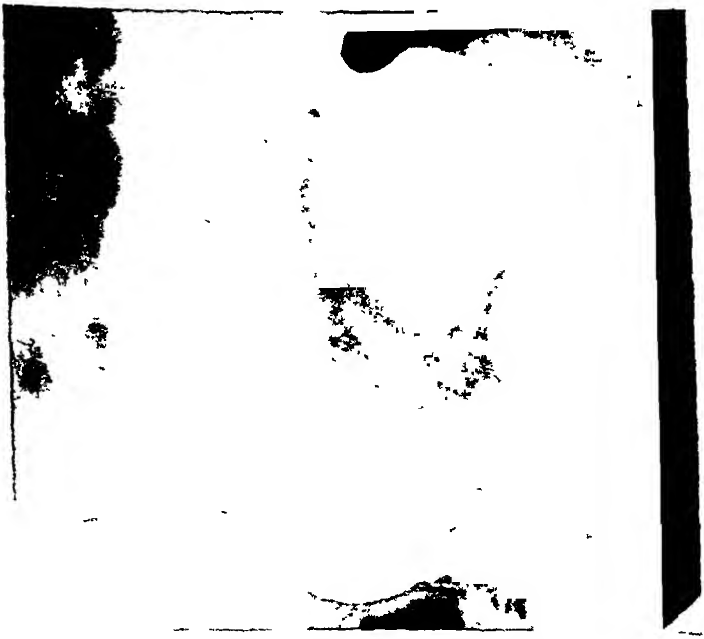

Fig. 137.—Extensive scirrhous carcinoma involving upper two-thirds of stomach.

entire stomach into a slender tube. Diminution of gastric capacity is a common feature of scirrhous carcinoma, and this results not so much from intrusion of the tumor, as from shrinking, shortening and loss of elasticity of the affected segment (Fig. 137). Ulceration is constant and occasionally deep but most often shallow, and usually the surface of the growth is relatively smooth. Consequently the internal relief often has a granular appearance somewhat like that of ground glass.

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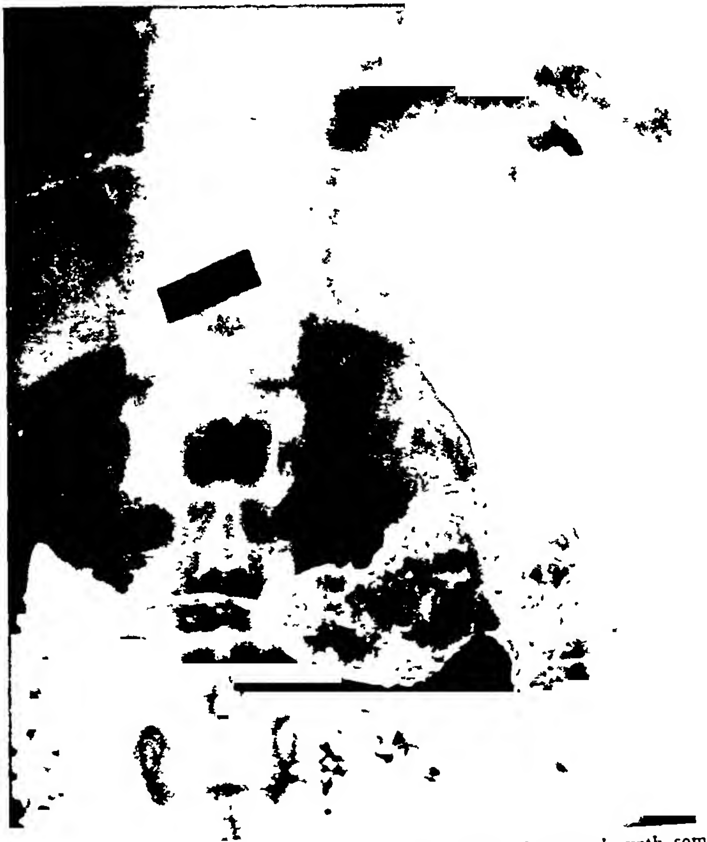

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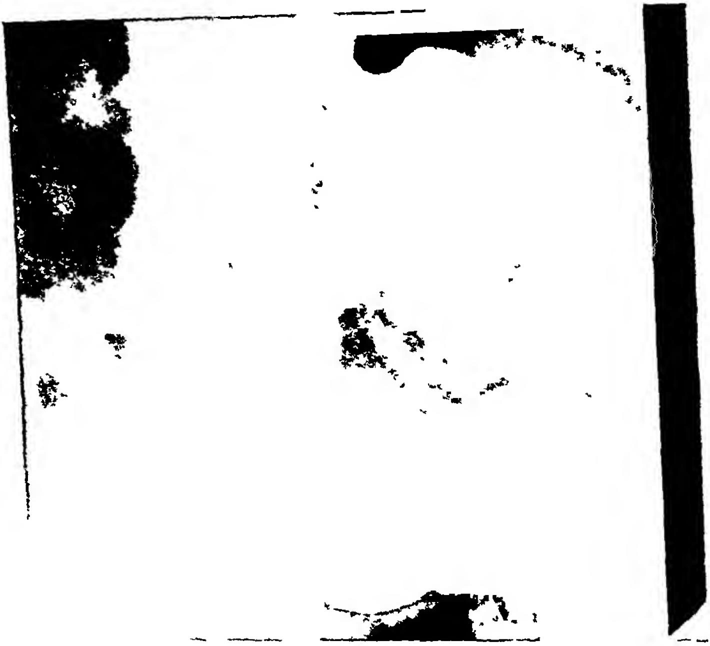

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Physical Signs and Secondary Manifestations.—Common to both varieties and to gastric cancer in general are certain physical signs and secondary manifestations. When the lesion is a frank tumor and is situated in the distal half of the stomach, which is accessible to palpation, the mass can be felt unless it is exceedingly small, and palpability of an intragastric tumor is strongly suggestive of malignancy. By extension of cancer to extragastric structures, or by the production of adhesions, the stomach may become fixed or less than normally mobile. Gastric rugae in the cancerous area are either smoothed out and effaced by the underlying tumefaction or destroyed by ulceration. As a rule peristalsis is absent from the region affected and is subdued in uninvolved portions of the stomach, although cancer obstructing the outlet may give rise to hyperperistalsis or antiperistalsis. Gastric motility is notably altered in most cases and almost without exception in those that are advanced. Unless obstructed, the pylorus commonly opens freely, the suspension of barium flows through it almost continuously, and the stomach empties quickly. However, obstruction occurs in about half of all cases and is evidenced by scant evacuation of the medium during examination and sometimes by obvious dilatation of the stomach.

In the presence of any of the foregoing manifestations the first task of the examiner is to determine that they are really due to gastric disease, for shadow defects and deformities, which are of fundamental diagnostic importance, may have many other causes, such as food or foreign bodies in the stomach, pressure by the spine, gastrospasm, retraction of the abdominal wall, and various extrinsic conditions, including ascites, advanced pregnancy, and abdominal tumors. These simulants and their characteristics are well known, and unless the examiner is familiar with them he should not attempt the examination. It may be said, however, that deformity produced by cancer is persistent as to site and configuration, withstands manipulation and remains unchanged at subsequent examinations. Distortion caused by simulants has none of these qualities.

Differential Diagnosis of Advanced Cancer.—When the presence of a lesion is definitely established, advanced cancer may require distinction from hernia of the stomach through the diaphragm, bezoar, benign neoplasm or gastric syphilis. *Hernia*

Fig. 138.—Incarcerated gastric hernia through esophageal hiatus with traumatic ulceration.

of a large portion of the stomach through the diaphragm distorts the viscus markedly and is sometimes mistaken for cancer, but the error is scarcely excusable for, in the case of hernia, part of the stomach is above the diaphragm and usually

this feature is plainly evident (Figs. 138 and 139). A large *bezoar* composed of hair, persimmon seeds or other material may be confounded with cancer because the mass is palpable, but the luminal contour is preserved and the shadow of the

Fig. 139.—Same case as that represented in Fig. 138, showing herniated portion of stomach filled with barium.

bezoar has a peculiar reticulated appearance (Figs. 140 and 141). Numerously multiple, closely packed *adenomas*, which usually are situated in the distal portion of the stomach, sometimes produce antral deformity that is superficially similar to

that caused by cancer (Fig. 142), but the adenomas are arranged in orderly rows like convolutions of the brain, and the picture is pathognomonic. Gastric *syphilis* closely imitates cancer (Fig. 143), especially the scirrhous variety, but it seldom produces a definitely palpable tumor and is so rare that, unless clinical evidence of the disease is strongly positive,

Fig 140—Large phytobezoar of persimmon seeds.

diagnostic preference should be given to cancer. On the whole, the roentgenologic differential diagnosis of advanced cancer is not often difficult, even for those whose roentgenologic experience is limited.

Cancer of the Cardiac Portion of the Stomach.—Whether advanced or early, cancer at this site is manifested variously by a shadow in the normally transradiant gas bubble (Fig. 144),

irregularity of the normally rounded and symmetrical dome and alteration of its internal relief. All these signs are best elicited with the patient standing, for they are likely to be effaced in the Trendelenburg posture formerly employed. By pressure on the lower portion of the filled stomach, the mucosa of the cardia can be coated with barium and thus inspected

Fig. 141.—Phytobezoar of which roentgenologic appearance is shown in Fig 140

more advantageously. Marginal irregularity due to cancer occurs more often on the internal border of the dome. Rarely, enlarged lymph nodes produce irregularity of this part of the cardia. Occasionally, also, the apex of the heart casts a visible shadow in the gas bubble, but the regular outline and pulsation of the shadow indicate its cause. As a rule, any of the signs

mentioned is fairly diagnostic of cancer, for other lesions of the cardia are extremely rare.

Early Cancer.—Some of the small and presumably early cancers, comprising infiltration and tumors without marked ulceration, deeply ulcerated tumors and malignant ulcers without apparent tumefaction, are hard to identify, even when situated in parts of the stomach that are easy to inspect, and

Fig. 142.—Polyposis of lower portion of stomach.

all of them are difficult to recognize when they are seated at or near the pylorus.

Relatively small *mucoid cancers* that are frank tumors without obvious ulceration are met with occasionally. The tumors have smooth, regular contours and, as they are often pedunculated, are likely to be mistaken for benign new growths, because, as a rule, intragastric tumors with such

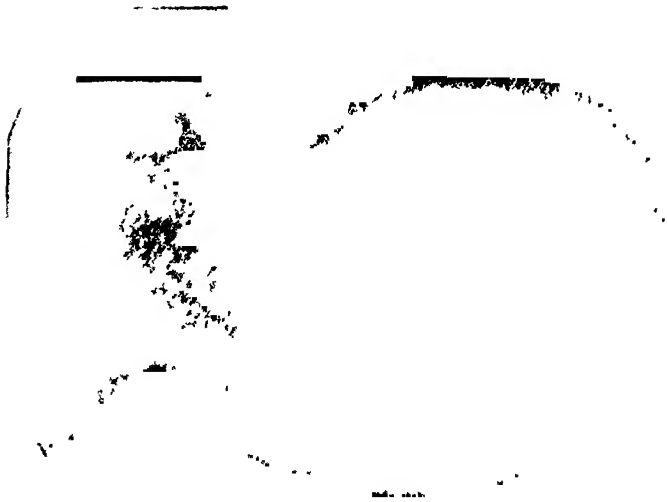

Fig. 143. Syphilis of pyloric segment of stomach.

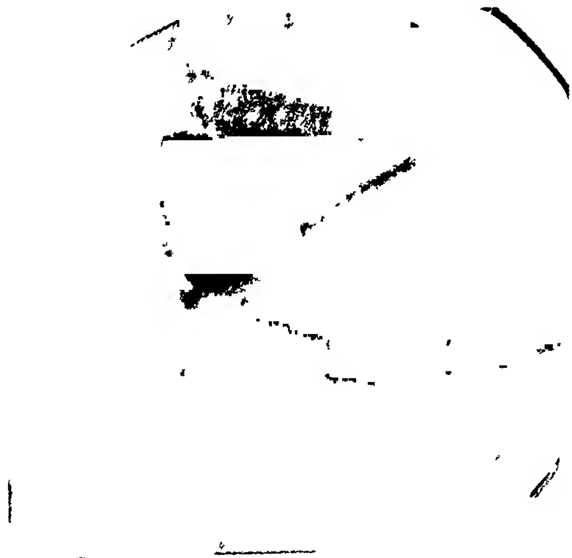

Fig. 144. Small carcinoma of cardiac portion of stomach as seen through gas bubble.

features are benign. However from a practical viewpoint, all efforts to distinguish malignant from benign new growths of

the stomach may be futile for often on microscopic examination cancer cells indicative of malignant change are found in gastric tumors that are made up chiefly of benign tissues, and polypoid tumors of the alimentary canal seem to be highly susceptible to such a change.

Early, or even moderately advanced, *scirrhous cancer,* is not readily discernible, for the limited infiltration seldom produces obvious marginal deformity. The mass is not likely to

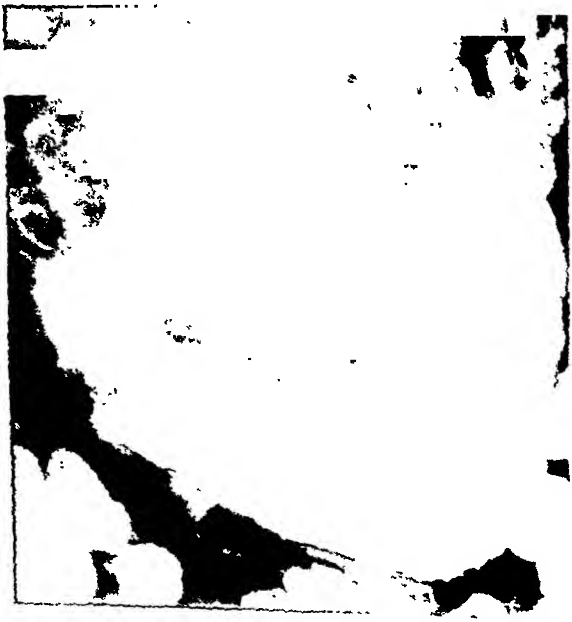

Fig. 145.—Small ulcerated carcinoma on lesser curvature at angle of stomach.

be definitely palpable, although it may tend to slip away under palpatory pressure, and usually, but not invariably, peristalsis is absent from the affected region. More conclusive than these signs is the granular internal relief of the involved region, which has the appearance of ground glass and is suggestive of scirrhous cancer.

Small, deeply ulcerated cancers in which a tumefied rim persists can be recognized with a high degree of accuracy, even

when the tumefaction is so slight that the excised lesion cannot be distinguished macroscopically from simple ulcer When the lesion is on the posterior wall, the elevated, sometimes overhanging, border appears under pressure as a transradiant halo about the dense, barium filled crater. When the cancer is on

Fig 146—Drawing of roentgenoscopic appearance of meniscus complex

the lesser curvature it is often possible by pressure to separate the shadow of the crater from that of the filled stomach and the crater, as seen edgewise, may have the form of a biconcave or concavo-convex lens, or meniscus In practically all instances the crater is not tender to pressure and gastrospasm is

conspicuously absent. These features in conjunction with the meniscus make up a sign complex that is pathognomonic (Figs. 145, 146 and 147).

Malignant Ulcers.—Malignant ulcers are cancers that morphologically are merely ulcers without macroscopic or roentgenologic evidence of tumefaction. When the niche of any gastric ulcer is unduly large and has a diameter exceeding 2.5 cm. it will prove usually, though not always, to be malig-

Fig. 147.—Resected specimen of small ulcerating carcinoma shown in Figs. 145 and 146.

nant. In many instances the niche is not excessively large, and other indications of malignancy have to be sought for, such as irregularity of the margin or base of the crater, effacement of adjoining rugae, and absence of gastrospasm or localized tenderness. A small percentage of ulcers that exhibit no roentgenologic marks of malignancy prove nevertheless on microscopic examination to be cancerous. (See Roentgenologic Diagnosis of Gastric Ulcer, elsewhere in this volume.)

Small Cancers at or near the Pylorus.—Whatever their

when the tumefaction is so slight that the excised lesion cannot be distinguished macroscopically from simple ulcer. When the lesion is on the posterior wall, the elevated, sometimes overhanging, border appears under pressure as a transradiant halo about the dense, barium filled crater. When the cancer is on

Fig 146—Drawing of roentgenoscopic appearance of meniscus complex

the lesser curvature it is often possible by pressure to separate the shadow of the crater from that of the filled stomach and the crater, as seen edgewise, may have the form of a biconcave or concavo-convex lens, or meniscus. In practically all instances the crater is not tender to pressure and gastrospasm is

Fig. 149.—Specimen from case represented in Fig. 148.

Fig. 150.—Characteristic pyloric deformity due to hypertrophy of the pyloric muscle.

morphology, these are hard to identify specifically. All varieties of cancer in this situation produce antral narrowing and apparent elongation of the pyloric canal, but similar manifestations may be caused by duodenal ulcer, hypertrophy of the prepyloric rugae, gastric syphilis, hypertrophy of the pyloric muscle, or benign gastric ulcer with spasm (Figs. 148 and 149). Occasionally both in cases of *duodenal ulcer* and of juxtapyloric cancer the bulbar base and pyloric ring are not

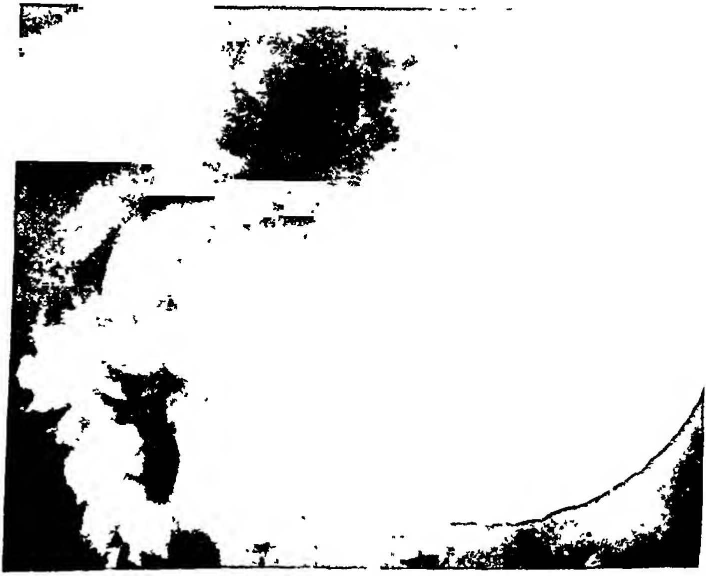

Fig. 148.—Prepyloric deformity with obstruction resulting from chronic gastric and healed duodenal ulcer

clearly demonstrable and, as the examiner is unable to determine whether the narrowing of the canal is prepyloric or postpyloric, he may confound either disease with the other. *Hypertrophic antral rugae* usually are recognizable by their orderly arrangement. Gastric *syphilis* is so rare that it can be discarded from consideration unless clinical and laboratory data point strongly to that disease. *Hypertrophy of the pyloric muscle* commonly produces definite invagination of the bulbar base and is marked also by a crevice near the middle of the

expert surgeons can perform extensive resections or even total gastrectomy if they deem it advisable. Total gastrectomy is facilitated when the subdiaphragmatic portion of the esophagus is unusually long, but such elongation is rare. Any operation on the stomach can be performed more easily when the epigastric angle—the angle between the right and left costal arches—is wide, and the converse is true if the angle is acute. Fixation of the growth by adhesions or extension to structures outside the stomach may hamper or even prevent resection.

Detection of Metastases.—Metastasis makes resection futile, and it is the most common obstacle to surgical intervention in cases that otherwise would be operable. Metastasis to the lungs, although it rarely ensues from gastric cancer, and metastasis to bones can be disclosed by suitable roentgenologic examination, but the rays will not disclose metastasis to abdominal lymph nodes or organs. Unfortunately such metastasis or some other unexpected deterrent is found at exploration in approximately half the cases that are operable as far as roentgenologic examination can determine.

elongated pyloric canal (Fig. 150). These marks occur rarely if ever in the other diseases named. When a niche is demonstrable, the lesion obviously is an ulcer, but the examiner cannot be certain whether it is malignant or benign. Marked tortuosity of the channel is suggestive of malignant tumefaction. In most cases of pyloric disease, however, the report "lesion at the outlet" will best serve the interests of all concerned, and it should be understood that unidentifiable lesions in this situation will prove to be malignant more often than benign.

Determination of Resectability.—In any case of gastric cancer the resectability of the lesion is the next problem to be solved after the diagnosis has been made. Manifestly, resectability depends considerably on the courage, customs and skill of the surgeon, but the general condition of the patient, the situation and extent of the growth, the mobility of the stomach, the width of the epigastric angle and the presence or absence of metastasis are factors of fundamental importance. Concerning most of them roentgenologic examination will furnish reliable and often decisive information. Ordinarily, cancer of or implicating the cardiac half of the stomach—roughly the portion above the angular incisure and the line of the left costal arch—is deemed inoperable. Cancer restricted to the pyloric third is resectable if there are no other factors that are prohibitive. Between the cardiac half and the pyloric third of the stomach is a zone of doubtful resectability, and the nearer the growth approaches the line of the left costal arch from below the more doubtful becomes its resectability, although under exceptionally favorable circumstances it may be possible to excise a cancer that has extended to the line of the arch or even slightly above the line. In adjudging the extent of invasion it is to be remembered that the shadow defect depicting mucoid cancer represents rather closely the actual limits of disease, but scirrhous cancer usually has infiltrated the gastric wall well beyond the limit indicated by the shadow defect, and liberal allowance must be made accordingly.

It will be recognized that these distinctions between resectable and nonresectable growths are more or less arbitrary, for

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THE ROENTGENOLOGIC APPROACH TO THE DIAGNOSIS OF INTESTINAL OBSTRUCTION

HARRY M. WEBER

DIFFICULTIES AND LIMITATIONS OF THE ROENTGENOLOGIC EXAMINATION IN GASTRO-ENTEROLOGIC DIAGNOSIS

The contribution of the roentgenologic method of examination to gastro-enterologic diagnosis has been so gratifying as perhaps to have encouraged a tendency to become preoccupied with its virtues, and to lose sight of the unfortunate fact that the method is encumbered by certain intrinsic difficulties and limitations. Not easy to explain, for instance, is its inadequacy in giving direct evidence of the presence, not to mention the nature, of certain functional gastro-enterologic disturbances which, if not neurogenic, are at least of extra-enteral origin. The difficulties referred to are inherent not so much in the method as they are in the *clinical situation* for the diagnostic clarification of which roentgenologic aid is sought. The patient, for example, for whom a complete roentgenologic examination of the gastro-intestinal tract is contemplated, must be well and hardy enough to cope with considerable inconvenience and annoyance. He must be moved to the roentgenologic laboratory; he must be able to take and retain the inevitable contrast suspensions administered orally and by rectum; he must not have an abdominal condition the clinical course of which might be affected adversely by these substances, or by delay in instituting emergency therapeutic measures, or by prolonged fasting, or by effective if not drastic purgation, or by even gentle manipulation through the abdominal wall. Some, occasionally all, of these potentially maleficent maneuvers must be introduced if the full diagnostic yield nowadays expected of the roentgenologic examination is to be obtained.

reach its diagnostic objective. A diagnostic technic of this kind is dangerous because the time consumed thereby is not well afforded by the patient, but chiefly because all commonly used contrast suspensions have a notorious tendency to become *impacted* above obstructing lesions, and thus are extremely likely to convert even a relatively benign clinical situation into a serious abdominal emergency.

The rule, then, is to avoid any procedure which involves oral administration of salts of heavy metals as contrast substances, or of purgative drugs in preparation therefor, in cases of acute or impending acute intestinal obstruction. Caution must also be observed in adapting such methods to cases of chronic obstruction, although a bolder attitude may be assumed if there is reliable evidence that the obstruction has been well compensated for.

THE SIMPLE ROENTGENOLOGIC SURVEY OF THE ABDOMEN

There is a simple roentgenologic test, easily done even at the bedside and with ordinary apparatus which, when interpreted properly and intelligently correlated with certain clinical findings, can be made to yield most pertinent diagnostic data on the presence, site and degree of intestinal obstruction, and in certain instances on the pathologic nature of the obstructing process. Because this test requires no preliminary preparation of the patient, nor the use of any kind of contrast material, it is not troublesome to the sick patient in any way, and is very quickly done. As a rule the diagnostic information obtained from the use of this test alone, correlated of course with the clinical history and findings, is sufficiently definitive to permit institution of proper therapeutic measures; if not, it serves, at least, to provide valuable clues as to the nature of the functional disturbance at hand, and to indicate what additional diagnostic procedures may safely be done further to clarify the problem.

The simple roentgenologic survey of the abdomen is in no sense a new test. Case was using it as early as 1910, and in 1915 discussed the diagnostic principles involved, while down

Every experienced physician knows, however, that situations arise in which, for one reason or another, the complete and ideal roentgenologic examination cannot, even should not, be attempted. *Intestinal obstruction*, acute or impending, is a prominent example of such a clinical situation. This does not mean that the roentgenologic method has a subordinate place in the solution of the diagnostic problems associated with intestinal obstruction, but it does mean that careful consideration is to be given to the potentiality for harm which certain of its diagnostic technics may have.

Dangers in the Oral Administration of Contrast Media in Obstruction.—*Obstructed hollow viscera are notoriously difficult to work with roentgenologically.* Whether the obstruction is in the esophagus, stomach, small intestine or colon, similar conditions producing similar difficulties to the roentgenologic examiner pertain. Orad to the site of an obstructing process distention always takes place. Associated with distention is suppression of effective peristalsis and of absorption. The dilated viscus becomes filled with abnormal intestinal secretions, ingested liquids and solids, and gas, the chief source of which is swallowed air. If this obstructing process is at or above the level of the ileocecal junction, vomiting, usually frequent and copious, sets in. Severe abdominal cramps, marked weakness and prostration further contribute to the morbidity, making the patient the very poorest kind of subject to undergo any type of complicated diagnostic maneuver.

Diagnostic procedures requiring administration of suspensions of opaque metallic salts or of purgative drugs in the preparation of the patient for such administration are, under these critical circumstances, not only impractical but dangerous. They are impractical because contrast suspensions become so widely dispersed in distended gastro-intestinal segments, becoming diluted in the abnormal secretions to the point of losing adequate contrast, and they usually fail to reach the site of obstruction, even when at a relatively high level, except after long lapse of valuable time. Thus the entire procedure fails to

supine abdomen. If for any reason perforation of an abdominal viscus is suspected a roentgenogram of the abdomen with the patient *standing or sitting* is made, centering the tube so as to include the diaphragmatic levels on the film. If the patient is too weak to stand or sit, an anteroposterior projection may be made of the same level with the patient in left lateral decubitus. *Free gas* in the peritoneal cavity will rise to be concentrated at the highest possible level, so that when the abdomen is erect it will be found under one or the other dome of the diaphragm, and in left lateral decubitus it is best seen between the right border of the liver and the abdominal wall, the dense mass of the liver enhancing the contrast. Free gas thus demonstrated in the peritoneal cavity of a patient not recently submitted to laparotomy is a sure sign of intra-abdominal perforation, although perforation of considerable magnitude is apparently necessary for the sign to be developed. It is not demonstrable in every instance of perforation.

Of the three projections just outlined, that of the abdomen supine is the most informative in the diagnosis of intestinal obstruction, and if but one roentgenogram is or can be made, this is the most desirable one.

As was noted earlier in this paper, intestinal distention of some degree is the inevitable consequence of intestinal obstruction. When the obstruction is severe enough to be manifested by clinical signs and symptoms it may be assumed that intestinal distention will be manifested at one or all of the roentgenologic examinations just outlined. It is the excessive accumulation of intra-enteral gas which provides the change in contrast necessary for the production of the roentgenoscopic and roentgenographic images of the distended intestine.

Interpretation of the Roentgenologic Findings.—Collections of gas are seen in various parts of the alimentary tract normally. The "gas bubble" of the stomach is familiar to everyone with any experience whatever in gastro-enterologic roentgenology. Small, sometimes large, collections of gas are seen in normal subjects, especially in the splenic and hepatic flexures. The normal small intestine, too, may contain gas in

the succeeding years many teachers of roentgenologic diagnosis have been insisting on its value, but with emphasis on the warning signals it produces. It was Wangensteen, however, who, on the basis of careful and well-controlled clinical observation and experiments in the laboratory, explained the phenomena exhibited in the test, defined clinicoroentgenologic criteria to put it on the solid foundation of observed facts, and did most to popularize its uses and advantages and to find for it a much wider application.

Technical Considerations.—Ideally this examination is made both roentgenographically and roentgenoscopically. When patients are very ill, however, as they usually are when suffering from intestinal obstruction, the first examination is most conveniently done at the bedside, using portable roentgenologic apparatus. A more satisfactory examination will of course be made in the roentgenologic laboratory, when roentgenoscopy and more efficient roentgenologic equipment, including the Potter diaphragm, are available for use. Roentgenographic factors of exposure time, kilovoltage, and target-film distance vary with the type of equipment at hand and with the density and thickness of the part to be examined. In general, the rule is to adopt a roentgenographic technic similar to that employed in roentgenography of the abdominal soft parts (kidneys, ureters, bladder), except that about 5 per cent greater penetration has been found to be of advantage. The central ray is directed at the midabdominal field, or if the clinical findings suggest a more pertinent localization, the tube may be centered more directly over this area.

Two standard projections are made, anteroposterior with the patient *supine*, and postero-anterior, with the patient *prone*. Roentgenographic projection of the abdomen with the patient prone makes possible a more reliable estimate of the true size of the mobile abdominal viscera, because in this position most of them crowd forward and thus get as near to the roentgenographic film as possible. Because of this crowding, however, it is frequently not possible to follow the arrangement of distended intestinal coils so easily as in the roentgenogram of the

infrequently seen in patients whose abdomen seems to be distended clinically, who complain of colicky abdominal pain, and in other ways suggest the presence or imminence of intestinal obstruction (Fig. 152). A syndrome of this kind seems especially prone to develop in persons unaccustomed to a

Fig 151.—Postoperative ileus Moderate distention of small intestine with gas No gas in colon after evacuant enemas. Distention began thirty-six hours after operation for acute appendicitis. Distention subsided spontaneously.

sedentary existence who are put to bed and given unfamiliar types of diet. The cause for the trouble is rarely made clear, since the symptoms disappear spontaneously or after a series of evacuant enemas. Distention of the colon persisting after one or several evacuant enemas is of course an important objective sign of obstruction. An isolated loop of large intestine

sufficient quantity to be demonstrable roentgenologically, but such collections have the appearance of small bubbles in isolated areas. Collections large enough to distend the small intestine recognizably beyond normal limits and to outline more than a few inches of it are not seen except in abnormal states. The stomach, small intestine and colon of infants, especially those fed at the breast or bottle, normally show gas in large quantities, probably only because they swallow large quantities of atmospheric air in feeding. Since the intestinal tract of children seems to be, and probably is, relatively longer than that of adults, it frequently seems to be distended when actually it is not.

The important determination to make is *the presence or absence of intestinal distention.* The intestinal gas is important only in that it serves, by its negative contrast value, to make the distended segment of intestine visible at roentgenologic examination. When the distention involves the *small intestine* this determination is made with relative ease. Large accumulations of gas do not occur except in states of intestinal stasis, and even a small degree of intestinal obstruction produces roentgenologic evidence of distention. In general it may be said that the greater the distention the more nearly complete is the obstruction. A distended coil of small intestine is recognized as small intestine by the circumstance that it occupies a central portion of the abdominal field, its course is at right angles to the longitudinal axis of the body, and when several loops are distended and contiguous, a very fine line demarcates the individual loops. When distention of a degree insufficient to obliterate them entirely exists, the characteristic connivent valves of jejunum and upper ileum serve to identify a distended loop as small intestine (Fig. 151).

It is much more difficult to determine the significance of gaseous distention of the *colon,* or of parts of it, on the basis of roentgenologic evidence alone. Only when it is very markedly distended should the diagnosis of obstruction be postulated unless the clinical evidence of obstruction is definitive. Very marked distention of the entire colon with gas is not

occupy, as does the transverse segment, the outer limits of the abdominal field. When distention is not so great as to obliterate them entirely, the characteristic haustra of the ascending and transverse divisions are also evident.

The *degree of obstruction* is, in general, represented by the *degree of distention* manifested in the roentgenologic examination of the abdomen. Marked distention may be exhibited, however, even when obstruction is incomplete, so the roentgenologic criteria are not definitive. Gaseous distention of the small intestine without evidence of gas in the colon generally means that the obstruction is in the small intestine and that it is complete. Complete obstruction of the colon quickly results in enormous distention, especially of the right colon, but only if the ileocecal sphincter is competent; otherwise distention will extend backward to involve small intestinal loops. At least some gas is always seen in the colon even when the obstruction is in the small intestine, and particularly when intestinal colic is severe. This more complex situation may be clarified by the administration of one or several evacuant enemas. The functional capacity of the intestine below an obstruction is not impaired, and therefore it can contract and expel its content when properly stimulated. Gas persisting in the colon after enemas, even without appreciable diminution of the small intestinal distention, signifies that the obstruction in the small intestine is incomplete (Fig. 153): if the gas can be made to disappear from the colon complete block of the small intestine is indicated. The diagnosis of incomplete obstruction of the colon is based on the finding of relatively minor degrees of distention of the colon associated with spontaneous passage of gas by rectum.

Correlation of the Roentgenologic Evidence with the Clinical Findings.—It must be emphasized that the diagnosis of intestinal obstruction is not to be based on roentgenologic evidence alone. The diagnostic data elicited at the roentgenologic examination, when properly correlated with carefully elicited and evaluated clinical signs and symptoms, will almost always serve to bring the ultimate diagnosis to a high degree

Left Right

Fig 152.—*Left*, Right half of colon distended with gas Roentgenogram made during an attack of renal colic Relief after passage of small, sharp, urinary calculus. *Right*, Moderate distention of entire colon with gas; small amounts of gas in small intestine Obstructing carcinoma of low descending colon discovered at examination with opaque enema

is recognized as such and distinguished from a loop of small intestine by the circumstance that its ascending and descending segments run parallel to the longitudinal axis of the body, and

possible the site of the obstructing process, its pathologic nature, and whether the obstruction is mechanical or inhibitive, simple or strangulating (Fig. 154). In general it may be said, however, that the greatest contribution this particular examination can make to the diagnosis is the establishment of the

Fig. 154.—Postoperative ileus. Patient had undergone combined abdominoperineal resection of the rectum for carcinoma about three weeks before this distention developed. Gradual decompression by suction. The actual cause of the distention was never determined. Adhesive obstruction? Inhibitive ileus?

presence or absence of intestinal obstruction, and locating the site in either the large or small intestine. Further elaboration of the diagnosis is much more a purely clinical problem.

It is true, of course, that there are certain roentgenologic signs on the basis of which a diagnosis of *inhibitive ileus* might

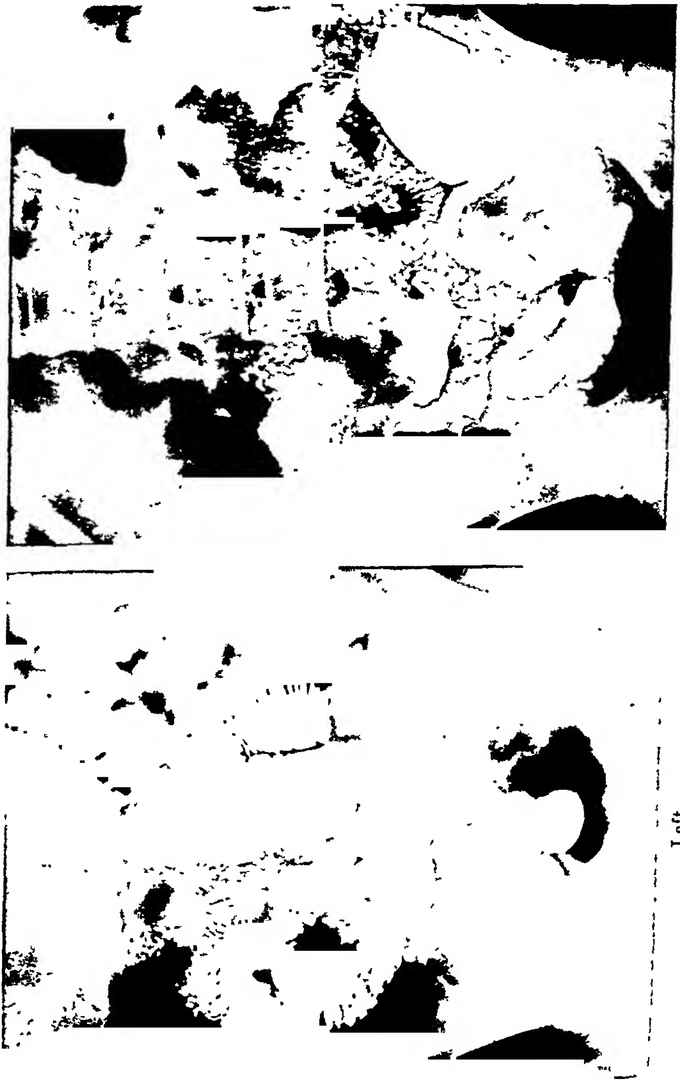

Fig. 153.—Demonstration of a malignant tumor of the mid-jejunum with the opaque meal. Early phase, *left*; later phase, *right*. The intestine above the constricting lesion is but slightly dilated. The gaseous distention of the colon is not satisfactorily explained, since at operation there was little evidence of obstruction in any part of the intestine. The lesion was not resectable. The pathologic diagnosis made from a piece of tissue removed at the operation was fibrosarcoma grade 3.

of accuracy. This holds true not only for the determination of the presence of distention, which when found in association with intestinal colic, means intestinal obstruction, but also in elaborating the diagnosis further to determine as precisely as

frequently should be had to *proctosigmoidoscopic examination* followed, if thereafter indicated, by roentgenoscopic examination with the opaque enema, to bring further evidence to bear on the diagnostic problem. If carefully done there are no serious contraindications to the use of these measures except the patient's inability, on account of weakness and prostration, to tolerate them. Both examinations are done in the usual manner, except that no purgative drugs should be administered to prepare the patient for them, and the least possible amount of the contrast enema should be allowed to flow through and above an obstructing lesion. The evacuant enemas administered to assist the large intestine in relieving itself of gas distending it from causes other than mechanical obstruction, serve to prepare the intestine adequately for the purposes for which these examinations are done under these circumstances. Extreme gentleness and care should be exercised always, but especially in the presence of localized or diffuse abdominal tenderness and muscular rigidity, for these suggest perforation or strangulation obstruction, the sinister import of which is obvious.

The expert proctosigmoidoscopic examiner is expected to find and identify the various stricture-forming lesions of the rectum and lower sigmoid colon, as well as such abnormalities as fecal impaction, congenital developmental errors and other processes with which low intestinal obstruction is associated. By roentgenoscopic examination with the opaque enema such abnormalities as intussusception, hernia, volvulus and megalocolon are, as a rule, immediately made apparent and recognized without great difficulty (Fig. 155). When intestinal obstruction is the result of adhesions, bands or compression of the intestine by extra-enteral processes, it must be assumed that the lumen of the intestine must have been seriously compromised, and so the fact of obstruction is readily established, but unless the intestinal lumen at the site of obstruction can be penetrated with the contrast fluid, little or nothing of value can be deduced about the pathologic nature of the obstructing process.

The problems of the examiner are similar when confronted

be postulated. Both the small intestine and colon are more or less markedly distended in this condition, the patient complains but little, and the abdomen when palpated at roentgenoscopic examination is relatively quiet. In some instances of inhibitive ileus, however, relatively few segments of the intestine are distended, so that a diagnosis on roentgenologic evidence alone would be quite impossible. Distinction between *simple* and *strangulating* obstruction is made exclusively on the basis of clinical findings.

Without the use of contrast suspension little can be expected from the roentgenologic survey of the abdominal field in the way of predicting the *pathologic nature* of the obstructing process. It does happen occasionally that the morphologic features of a constricting or intussuscepting lesion, especially of the large intestine, are so clearly delineated by the gas-distended intestine just above it, that an anatomic diagnosis can be made on this basis. For the most part, however, even with full access to all diagnostic data derived from clinical sources and from the laboratory, conclusions regarding the pathologic nature of an obstructing process are at best inferential unless supplemented by further roentgenologic studies.

Still insufficiently appreciated is the restraining influence the roentgenologic test now under consideration exerts on the examiner in instances in which evidence of acute or impending acute intestinal obstruction has been elicited. The prudent observer will then proceed with the administration of contrast suspensions, and of purgative drugs in preparation of the patient for such administration, only with extreme caution, and with full knowledge and consent of his clinical and surgical consultants. If decision is made to proceed with more refined roentgenologic tests he will be apprehensive enough to have arranged in advance for the therapeutic management of any adverse contingency that may develop subsequent to or as a result of his administrations.

ROENTGENOLOGIC EXAMINATION WITH THE OPAQUE ENEMA

When there is substantial clinical and roentgenologic evidence that the large intestine is obstructed, recourse may,

If the entire extent of the constricted intestine can be visualized by distending it with the opaque enema, then criteria are elicitable by means of which the neoplastic lesions are distinguished from the non-neoplastic ones. This obviously is a critical distinction to make, for the subsequent therapeutic approach depends on it. Radical therapy will be undertaken if reliable evidence of neoplasm is developed; a more conservative therapeutic approach is indicated if the lesion can be shown to be non-neoplastic. Even when a neoplastic lesion has become extensively infected, under which circumstances it takes on the anatomic, hence the roentgenologic, character of an inflammatory tumefaction, that fact can be determined roentgenologically.

It is not possible, as a rule, to distinguish roentgenologically between the various kinds of non-neoplastic tumefactions which occur in the colon, but valuable diagnostic clues are almost always made available. A constricting lesion in the sigmoid colon, for instance, lacking the positive roentgenologic signs of neoplasm, but associated with roentgenologically visualized colonic diverticula, will almost always prove to be *diverticulitis*. Similarly, a constricting lesion in the ileocecal coil, also lacking the positive evidences for neoplasm, but associated with an active focus of tuberculosis of the lungs, will almost always prove to be an ileocecal *tuberculoma*. Again, if a tender stricture-like lesion is found in the hepatic flexure of a patient with clinical and roentgenologic evidences of cholecystitis, in addition to intestinal symptoms, often he will prove to have suffered *perforation* of the gallbladder with pericholecystic and pericolic abscess formation to account for the intestinal symptoms and findings. It must be recalled, however, that diagnoses like these are possible, as a rule, only when the lumen at the site of the constriction can be visualized in its entirety by passing the contrast fluid through it.

Unfortunately when obstruction is complete, or nearly so, the lumen of the affected portion of intestine is no more pervious from above than from below, and so it happens all too frequently that roentgenologic observation with the con-

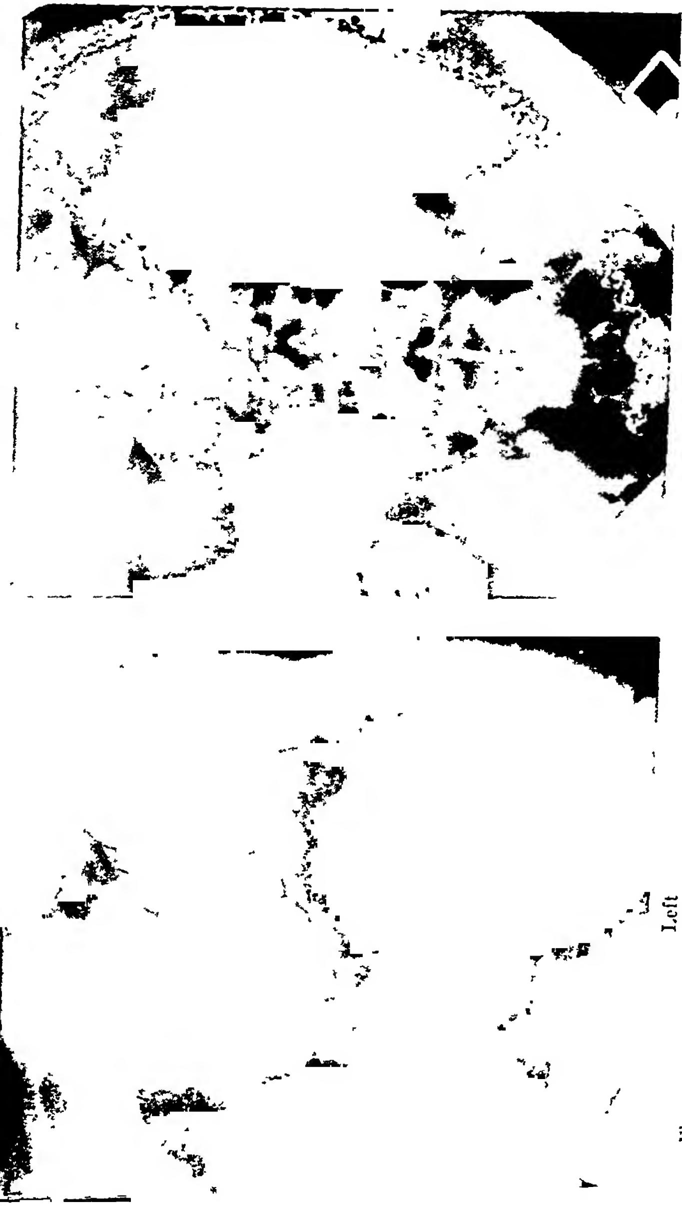

Fig 155.—The typical roentgenologic picture of intussusception Opaque enema, *left*; roentgenogram after evacuation of opaque enema, *right*. The patient was a man, forty-eight years old, who had intermittent attacks of epigastric distress for six weeks. Roentgenologic diagnosis: Colocolic intussusception. At operation an intussuscepting myxoma arising in the ileum 15 cm. above the ileocecal valve was found The lesion measured 6 by 5.5 by 4.5 cm. There was also a marked ileitis in the invaginated portion of ileum. The patient was dismissed, well, twenty-four days after the operation The lack of evidence of distention is noteworthy.

with one of the stricture-forming *neoplastic* and *non-neoplastic tumefactions.* Again the fact of obstruction is obvious at once.

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trast enema fails to advance the solution of the diagnostic problem enough to compensate for the time and inconvenience its use entails. It finds its greatest usefulness in low and moderate degrees of intestinal obstruction shown, in the preliminary roentgenologic survey of the abdomen, to be located in the colon or lowermost ileum. Even if, for one reason or another, the exact pathologic nature of a lesion or condition causing mechanical obstruction in the colon or terminal ileum cannot be determined, the fact of obstruction, at least, can always be established by the combined use of the proctosigmoidoscopic examination and roentgenologic observation with the contrast enema. Any failure in this respect is to be attributed not to inadequacy of the methods, but to temporary lack of proficiency on the part of the person trying to use them. Conditions like hernia, volvulus and intussusception must, of course, be seen at the time when they are actually operative in producing intestinal obstruction. They do have a certain tendency to be reduced as spontaneously as they developed, and in their reduced phases no intrinsic abnormality is likely to be apparent when the intestine is examined proctosigmoidoscopically or roentgenologically.

ROENTGENOLOGIC EXAMINATION WITH ORALLY ADMINISTERED CONTRAST MEDIA

Little of real diagnostic import is accomplished, in instances of moderate to high degrees of intestinal obstruction, from orally administered contrast suspension followed roentgenologically as it makes its way down the intestinal tract toward an obstruction, unless the obstruction happens to be no lower than the upper third or so of jejunum. The impaction resulting from administration of suspensions of the insoluble salts of the heavy metals barium and bismuth contributes, often greatly, to the morbidity of intestinal obstruction by increasing its degree. Oral administration of such suspensions, no matter how prepared, are definitely *contraindicated* whenever clinical and roentgenologic evidence indicates (1) that obstruction is complete or nearly so, and (2) that, even if of low or moderate

degree, it is located in or below the lower two-thirds of small intestine.

Nowadays *barium sulfate* is the opaque salt used in roentgenologic work practically to the exclusion of all others. Some roentgenologic examiners try to circumvent the danger of impaction by administering the substance in diminished quantity, either by giving a small volume of the standard or routine concentration, or by giving the standard volume of a considerably diluted suspension. Others substitute for barium sulfate a commercially prepared colloidal suspension of *thorium dioxide* which is inherently much more opaque to roentgen rays and does not become impacted. Still others advocate delivery of the preparation of barium directly to the site of obstruction through a duodenal tube previously allowed to pass down to this level, with the idea of withdrawing the opaque fluid by suction when it has served its diagnostic purpose. All of these maneuvers are attended with practical disadvantages. Colloidal thorium dioxide is inordinately expensive and otherwise difficult to obtain. Any opaque fluid added to the fluid and gaseous contents of distended intestinal loops is sure to be widely dispersed, unevenly mixed, and diluted to the point of losing adequate contrast. The greater the degree of distention the more effectively intestinal motility is subdued, and so the time required for roentgenologic examination is likely to be extended beyond practical limits, especially if obstruction of considerable degree has taken place.

I have had no cause to be impressed with the use of the *intestinal tube* as a roentgenologic diagnostic instrument, regardless of the manner or form in which I have seen it used. Here again the time element has been confounding. To be capable of yielding diagnostic information of consequence the tip of the tube, at least, must reach the site of obstruction, and this is always a matter of hours, sometimes of days. Then, when it has reached or even passed through the intestinal lumen at the site of block, nothing of real diagnostic import beyond the fact of obstruction seems ever to be revealed. Intestinal tubes of the Miller-Abbott type seem to me to have

trast enema fails to advance the solution of the diagnostic problem enough to compensate for the time and inconvenience its use entails. It finds its greatest usefulness in low and moderate degrees of intestinal obstruction shown, in the preliminary roentgenologic survey of the abdomen, to be located in the colon or lowermost ileum. Even if, for one reason or another, the exact pathologic nature of a lesion or condition causing mechanical obstruction in the colon or terminal ileum cannot be determined, the fact of obstruction, at least, can always be established by the combined use of the proctosigmoidoscopic examination and roentgenologic observation with the contrast enema. Any failure in this respect is to be attributed not to inadequacy of the methods, but to temporary lack of proficiency on the part of the person trying to use them. Conditions like hernia, volvulus and intussusception must, of course, be seen at the time when they are actually operative in producing intestinal obstruction. They do have a certain tendency to be reduced as spontaneously as they developed, and in their reduced phases no intrinsic abnormality is likely to be apparent when the intestine is examined proctosigmoidoscopically or roentgenologically.

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obstruction. Wangensteen and others have emphasized strongly that the most pernicious type of obstruction of all is that occurring acutely in the pelvic colon. If the ileocecal valve is competent enough to resist the high intracolonic pressure developing with acute obstruction in the lower half of the large intestine, a closed loop obstruction is effected. and cecal perforation is then imminent.

SUMMARY

The roentgenologic approach to the diagnosis of intestinal obstruction begins with the survey of the abdominal field for evidence of intestinal distention. If such evidence is absent, then it is usually safe to proceed with the routine type of examination of the intestinal tract. When evidence of intestinal obstruction is at hand, then caution is the watchword. The site, degree, and possible nature of the obstruction as determined by careful and intelligent elaboration and interpretation of the clinical and roentgenologic findings will determine the subsequent diagnostic procedure. In the interest of safety the investigation is best pursued from the aboral aspect of the suspected site of the lesion. Proctosigmoidoscopic examination and roentgenologic observation of the opaque enema are instituted first to exclude the rectum, colon and lowermost ileum as sites of obstruction. In general, the giving of purgative drugs and contrast media by mouth is studiously avoided, at least until complete decompression has been effected, but even then only with their potentiality for harm in mind. Judiciously applied and interpreted in the light of experience, and in careful correlation with the clinical history and with the findings of the physical examination and of the clinical laboratory, the roentgenologic examination can be made to clarify many a difficult situation, often to deliver a precise preoperative anatomic diagnosis.

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no particular advantages in this respect. In isolated instances it may be possible to gain more precise information about the nature of an obstructing process with a complicated technic developed in one way or another around one of the many modifications of the intestinal tube, but in my experience a favorable result has been the exception, not the rule. This much certainly is true, that when special caution about causing contrast media to be placed orad to an obstructing process is indicated, the information to be gained thereby can be expected to be limited, no matter in what manner the medium is administered. The lower the degree of intestinal obstruction, of course, the less specifically is the oral use of contrast medium contraindicated but, when used, arrangements for its immediate removal by use of suction through the intestinal tube should have been made in advance to deal properly with any difficulties that might ensue.

The principle, developed largely by Wangensteen and then promulgated by him, of applying *suction* to an indwelling intestinal tube for the purpose of relieving intestinal distention, has advanced the therapy of intestinal obstruction immeasurably. Certain types of obstruction are known to yield to this method of treatment alone. This form of treatment, moreover, is indicated in every type of intestinal obstruction not complicated by strangulation or by other factors acutely and seriously threatening the viability of the intestinal wall. Its essential function is *decompression*, and when successful an acute obstruction is converted into a subacute or chronic one, enabling the intestine gradually to adapt itself to the effects of obstruction, although the primary cause may not be directly influenced. The progress of decompression is observed roentgenographically while suction is in force. After successful decompression, contrast suspensions can be given by mouth more boldly and effectively, for effective intestinal motility will have been restored, distention reduced and conditions in general improved to the point where a really satisfactory roentgenologic examination can be conducted. The colon, especially its lower segments, must have been excluded as the site of

obstruction. Wangensteen and others have emphasized strongly that the most pernicious type of obstruction of all is that occurring acutely in the pelvic colon. If the ileocecal valve is competent enough to resist the high intracolonic pressure developing with acute obstruction in the lower half of the large intestine, a closed loop obstruction is effected, and cecal perforation is then imminent.

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